The Employment Impact of the NortH2 Project

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Executive Summary

This report describes the methods and scenarios developed to estimate the employment impact of the NortH2 project, which in a first phase until 2030, aims to develop a large-scale hydrogen-driven energy infrastructure, starting in the Northern Netherlands, with the Eemshaven (near Delfzijl) as its main hub. The employment impact of this first phase has been estimated for the province of Groningen, for the three Northern provinces taken together and for the Dutch economy as a whole. The semi-closed input-output model (which does not only take direct and indirect employment impacts into account, but also effects due to additional consumption demand induced by higher income levels) has been used, in combination with regional input-output tables specifically constructed for this project.

Based on information from documents provided by the NortH2 consortium and information obtained from experts in the field, the initial impacts (expressed in millions euros and/or direct employment) of the investments have been estimated. This has been done for five ‘subprojects’ of which NortH2 consists: the wind farm, the offshore power infrastructure, the electrolyser factory, transport of hydrogen via pipelines and the storage (in caverns).

The eventual employment impact is uncertain, because it is yet unknown which companies will win major contracts to supply important parts of the infrastructure required for this very large project. The regional employment effects will be considerably higher if Groningen-based firms win such contracts than in a situation in which foreign companies without production facilities in the region or country appear as the most successful tenderers. Therefore, two scenarios have been formulated, for each of the subprojects and for the entire NortH2 project. In one scenario, regional or national firms are very successful in winning contracts. In the other scenario, firms outside Groningen or The Netherlands outcompete regional or national rivals in many more cases.

We find that in the first phase of the NortH2 project roughly between 5,000 and 12,000 man-years of employment will be generated in Groningen in the installation phase of the project. For the Northern Netherlands, the corresponding lower and upper bounds are roughly 9,000 and 16,000, while these are 14,000 and 50,000 for the national economy. On a more permanent basis, maintenance and asset ownership activities will create about 1,000 jobs in Groningen, and about 1,300 and 1,900 in the North and the entire Netherlands, respectively.

These long-run employment effects for Groningen and the Northern provinces would have a positive impact on employment if most of the labor demand would be for medium-skilled workers and if the project would be accompanied by substantial investments in knowledge and skills generation. This should happen in early stages of the project, to enhance the chances that a competitive advantage (over other regions, both in The Netherlands and abroad) can be attained.

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1. Introduction

Over the past years, plans have been developed to install a huge green hydrogen infrastructure in the North of the Netherlands by 2030. It would involve the construction of a 4 gigawatt windfarm in the northern part of the North Sea, offshore and onshore power infrastructure, an electrolyser factory in the Eemshaven, repurposing of existing and installing new pipeline infrastructure for the transport of hydrogen to of the major industrial demand clusters in The Netherlands and the Western part of Germany, and the preparation of salt caverns and associated equipment for the storage of hydrogen. The project has been labeled "NortH2". The above development is just the first phase of the NortH2 project. In a second phase, an additional 6+ GW offshore wind dedicated to hydrogen production will be developed, resulting in 10+ GW offshore wind to hydrogen production by 2040 when the project is fully developed.

The costs involved in such a major investment project are very large, but might well bring substantial revenues as well. First and foremost, the investment plan would contribute heavily to the transition from a fossil fuels-based economy to an economy in which renewable energy accounts for large shares of national energy use. This transition must materialize rapidly in order to meet international agreements aimed at preventing excessive global warming. Second, the project would have positive employment effects. Substantial parts of the project will be located in the province of Groningen. With the exception of its capital city, the province is one of the economically weaker regions within The Netherlands, with relatively low household incomes and relatively high unemployment rates. Hence, NortH2 could provide a welcome economic boost to this region. This report focuses on the employment effects of NortH2, for the province of Groningen, the three northern provinces in The Netherlands (Groningen, Drenthe, Friesland), and for the national Dutch economy.

In quantifying these effects, we use two major sources of information. First, we used information as contained in documents containing the business case for the project. Complemented with expert opinions on the composition of the investments (regarding the types of products required as well as the location of the most likely suppliers of these), this information allowed us to quantify the direct effects. Indirect effects were also considered. The production of a machine requires metal products, the production of which also entails labor inputs. Moreover, additional labor income induces households to consume more. These effects were quantified using input-output tables. To arrive at detailed input-output tables for the province of Groningen and for the Northern Netherlands, we merged information from input-output data compiled by PBL Netherlands Environmental Assessment Agency with data from Statistics Netherlands.

NortH2 is unique in terms of its size. This implies that the data regarding the direct effects do have a rather wide margin of uncertainty. It also remains to be seen which firms will win contracts for construction activities and the delivery of key supplies. It matters for the employment effects whether these firms will be located in Groningen, elsewhere in The Netherlands, or abroad. To tackle such uncertainties, we adopted a scenario approach. For each of the five subprojects, we formulated a "maximum" and "minimum" scenario, which we describe in the table below. The differences between the two scenarios give an indication of the degrees of uncertainty.

The remainder of this report is structured as follows. Section 2 describes the numbers we used in both scenarios for each of the five subprojects. Section 3 presents an accessible discussion of the construction of the input-output tables for Groningen and the Northern Netherlands and the associated employment coefficients. This section also shows how these data can be used to compute economywide employment effects of investment projects. The estimated employment effects of NortH2 are presented in Section 4. Section 5 concludes and discusses some potential broader implications of the project for the long-term economic performance of the province of Groningen and the Northern Netherlands.

2. Scenarios

The employment effects of NortH2 on the province of Groningen, the Northern Netherlands (including Groningen) and the Netherlands (including the North) are dependent on many different decisions. The most impactful are those that relate to which firms will be selected to supply the most important goods and services required for the project. The investments are very large, which implies that EU tendering regulations will have to be obeyed. Consequently, it is in many cases unclear whether contracts will be won by companies in the Netherlands or from abroad. If Dutch companies are more successful, the employment effects in the Netherlands (or in the Northern parts of it) will generally be larger than if other companies are selected as suppliers. The differences are not only related to direct effects (Dutch firms will generally mainly employ workers in the Netherlands), but might also be caused by indirect effects. Global input-output tables such as those contained in the World Input-Output Database (see Timmer et al., 2015) show that, Dutch firms tend to purchase a larger share (in comparison to foreign companies) of their materials, parts, components and business services in the Netherlands.

There are areas in which Dutch companies will likely not (be able) to compete with other companies. As indicated by experts we consulted, it is unlikely that Dutch firms can successfully compete with Danish, German and American producers of wind turbines. In such a case, there is no need to work with different scenarios. According to an industry expert, a company in Rotterdam might well become the supplier of the "foundations" of the turbines. It has the capabilities, but it remains to be seen whether it will win the contract (or part of it) to supply these foundations. In cases like these, we worked with a "maximum" and "minimum" scenario. In the minimum scenario, we assume that Dutch firms in general and Northern/Groningen firms in particular will not be very successful in winning contracts. In the maximum scenario, we assume that Dutch companies and companies in the North/Groningen will be successful in winning contract.

The location of companies that become the winning tenderers is the main source of uncertainty, but not the only one. In some cases, the composition of the investments is not entirely clear yet. This uncertainty often relates to technological choices that still have to be made. In other cases, the sheer uniqueness of the project (regarding its size in particular) implies that rules-of-thumb regarding the levels of investment required is perhaps not accurate and the extent to which economies of scale apply is uncertain.

The confidential business case document as supplied to us by the NortH2 consortium gave us information about the CAPEX (the capital expenditure to build the project) and the OPEX (the annual operational expenditure for maintenance, reparation and organization of the day-to-day operations, "asset ownership"). The business case also contained some information about the composition of these costs. We obtained additional information from a number of experts, working for Gasunie, Shell and for knowledge institutions in the relevant fields. We used these sources of information to quantify the maximum and minimum scenarios for five subprojects that together constitute the NortH2 project: (1) the offshore wind farm, (2) the offshore and onshore power infrastructure, (3) the electrolyser factory, (4) the transport infrastructure, and (5) the storage facilities. Adding up the employment impacts of the maximum scenario for these five subprojects gives us the maximum scenario for the NortH2 project as a whole, and the same method is applied to get the employment impact in the minimum scenario.

If possible (given the available information) we make a distinction between the estimated number of people directly employed by suppliers of goods and services and the employment associated with acquiring materials. The latter lead to indirect employment effects in industries supplying these intermediate inputs. In some cases, we did not have such a split and assumed that the "average" production technology in supplying industries will apply. In all scenarios, we assume that the wage rate of workers involved is on average equal to that of the Dutch average.

Table 1 contains quantitative information regarding the two scenarios for each of the five subprojects. As mentioned before, we make a distinction between once-off investments and operational expenditures that will have to be incurred annually.

Table 1a: Description of Scenarios (Wind Farm)

	"Maximum" Scenario	"Minimum" Scenario
Initial investment	Turbines produced outside The Netherlands; Monopiles and transition pieces produced in Rotterdam; Steel for monopoles and transition pieces produced in IJmuiden; Groundwork and preparation by Dutch company (75% Dutch employment, outside Northern Netherlands); Specialized installation partly by Dutch company (50% Dutch employment, outside Northern Netherlands).	Turbines produced outside The Netherlands; Monopiles and transition pieces produced abroad; Steel for monopoles and transition pieces produced abroad; Groundwork and preparation by foreign company; Specialized installation only partly by Dutch company (25% Dutch employment, outside Northern Netherlands).
Annual maintenance, etc.	50% of the annual maintenance work done by Groningen-based workers, 25% by workers in the rest of the Northern Netherlands, 20% by workers elsewhere in The Netherlands.	25% of the annual maintenance work done by Groningen-based workers, 10% by workers elsewhere in The Netherlands (not in the Northern Netherlands).

Table 1b: Description of Scenarios (Offshore Power Infrastructure)

	"Maximum" Scenario	"Minimum" Scenario
Initial investment	HVA offshore station produced and installed by foreign company Cables supplied and installed by Dutch company (from elsewhere in The Netherlands) Onshore substations supplied and installed by Dutch company (from elsewhere in The Netherlands) 150 fte-years work for foreign workers living in Groningen 15% of CAPEX for supplies by Groningen-based firms	HVA offshore station produced and installed by foreign company Cables supplied and installed by Dutch company (from elsewhere in The Netherlands) Onshore substations supplied and installed by Dutch company (from elsewhere in The Netherlands) 150 fte-years work for foreign workers living in Groningen 10% of CAPEX for supplies by Groningen-based firms
Annual maintenance, etc.	All maintenance work by foreign firms, remotely and on fly-in, fly-out basis 20% of OPEX supplied by Groningen-based firms (mainly in security services, administration, construction)	All maintenance work by foreign firms, remotely and on fly-in, fly-out basis 10% of OPEX supplied by Groningen-based firms (mainly in security services, administration, construction)

Table 1c: Description of Scenarios (Electrolyzer Factory)

	"Maximum" Scenario	"Minimum" Scenario
Initial investment	Electrolyzers and power electronics supplied by foreign companies; Cooling machinery and related equipment produced by Dutch (non-Northern) company; Civil engineering etc. (30% of the CAPEX): 75% by Groningen-based firms, 25% by firms based elsewhere in the Northern Netherlands.	Electrolyzers and power electronics supplied by foreign companies; Cooling machinery and related equipment produced abroad; Civil engineering etc. (20% of the CAPEX): 25% by Groningen-based firms, 50% by firms based elsewhere in the Northern Netherlands, 25% by firms elsewhere in The Netherlands.
Annual maintenance, etc.	80 fte employment in asset ownership; 10% of maintenance work by Groningen-based companies.	60 fte employment in asset ownership; 10% of maintenance work by Groningen-based companies.

Table 1d: Description of Scenarios (Transport)

	"Maximum" Scenario	"Minimum" Scenario
Initial investment	New pipelines purchased abroad; Valves supplied by Dutch company (not in Northern Netherlands); Cleaning and preparation of existing pipelines: 50% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 10% by other firms in the Netherlands (and 15% by firms abroad).	New pipelines purchased abroad; Valves purchased abroad; Cleaning and preparation of existing pipelines: 25% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 30% by other firms in the Netherlands (20% by firms abroad).
Annual maintenance, etc.	Maintenance activities: 50% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 10% by other firms in the Netherlands (and 15% by firms abroad).	Maintenance activities: 25% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 30% by other firms in the Netherlands (and 20% by firms abroad).

Table 1e: Description of Scenarios (Storage)

	"Maximum" Scenario	"Minimum" Scenario
Initial investment	Factory construction: 50% by Groningen-based companies, 25% by firms elsewhere in the Northern Netherlands, 25% by other Dutch companies; Caverns: 50 fte per year direct employment during six years, all Groningen-based. Machinery and components produced in the Netherlands (but not in the North); Cushion gas: 25% purchased in Groningen, 25% elsewhere in the Northern Netherlands, 50% from other Dutch suppliers.	Factory construction: 25% by Groningen-based companies, 25% by firms elsewhere in the Northern Netherlands, 50% by other Dutch companies; Caverns: 50 fte per year direct employment during six years, 50% Groningen-based, 50% elsewhere in the Northern Netherlands. 50% of machinery and components produced in the Netherlands (but not in the North), 50% abroad; Cushion gas: 10% purchased in Groningen, 20% elsewhere in the Northern Netherlands, 70% from other Dutch suppliers.

Annual maintenance, etc.	Maintenance activities: 50% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 10% by other firms in the Netherlands (and 15% by firms abroad). Metal products supplied by Dutch (non-Northern) firms.	Maintenance activities: 25% by Groningen-based firms, 25% by firms elsewhere in the Northern Netherlands, 30% by other firms in the Netherlands (and 20% by firms abroad). Metal products supplied by Dutch (non-Northern) firms.

3. Construction of Input-Output Tables and Employment Data

Estimating the direct effects of investment projects like NortH2 relies heavily on the type of expert information that provided the basis for the scenarios presented in the previous section. Just focusing on these would underestimate the employment generated by such projects, since indirect and induced effects can be substantial. *Indirect* effects are defined as those effects that are caused by interindustry input linkages. A construction company needs cement and metal products, for example. It purchases these from firms in the stone products and cement industry and the fabricated metal products industry, respectively. These firms, in turn, employ labor and use parts, materials and services from other firms in "upstream" industries. *Induced* effects relate to additional consumption demand by households, induced by wage and salary payments due to the investment project. Workers moving to the province of Groningen will spend part of their budgets in local supermarkets, they will have their repairs done by local suppliers and they will pay membership fees to local sports clubs or gyms. This additional consumption demand causes further increases in employment, not only in Groningen's retail trade industry, its installation and repairments industry and its recreational services industry, but also in industries supplying to these. In line with the input-output table for The Netherlands in 2017 as published by Statistics Netherlands (see below), we assume that every euro of additional wages paid cause 0.25 cents of additional consumption demand by households.

We will use Leontief's 'semi-closed' static input-output model to estimate the employment effects, explicitly incorporating indirect and induced effects. This is a rather common tool for such analyses, see e.g. Miller and Blair (2009). Like any model, it has its advantages and disadvantages. In our view, its main advantage is its transparency. The entire model can be presented in three or four equations that convey a clear intuition (see Appendix A), despite the rich interindustry detail incorporated by it. Downsides are that it assumes that labor (and, implicitly, physical capital goods) is available in such quantities that increases in demand do not imply higher wage rates (or rental rates of capital). Moreover, production processes are assumed to have a constant returns to scale nature, which means that all inputs used by an industry have to increase by x% if its output grows by that same x%. In addition, the semi-closed static model in specific assumes that upstream industries can produce additional output by purchasing more intermediate inputs and hiring more labor, but without investing more in physical capital. Finally, it assumes that all households in the economy considered spend constant shares of their labor income on consumption of specific products, irrespective of how much they earn and that non-wage income (e.g. deriving from profits) are saved (or spent outside the economy considered). Many of these strict assumptions are relaxed in "computable general equilibrium" (CGE) models, but the outcomes of these depend on fixing hundreds of model parameters and the outcomes are often intractable. Hence, CGE models are often viewed as "black boxes" (see, e.g. Boehringer et al., 2003). In terms of model outcomes, employment effects estimated using input-output models tend to be larger than those obtained using CGE models (see West, 1995).

In our view, the quality of the data fed to the model is most likely more fundamental for the accuracy of the estimates than the very specific type of model used in analyses of the impacts of large investment projects. Of course, the strengths of the economic linkages between industries in the economy considered must be measured well in order to obtain good estimates of the indirect effects. This implies that the input-output tables used should contain a lot of industry detail. In the extreme case in which all production processes would be captured in a single sector, the implicit assumption would be that all industries in the economy considered produce with the same technology. This would not only imply that they would use (per euro of output) the same quantities of intermediate inputs but also the same quantities of labor, which is clearly unrealistic and would lead to large "aggregation biases" (see Miller and Blair, 2009, section 4.9). Ideally, we would like to have an input-output table in which every firm or even every establishment would be represented by its own industry, which would allow for taking all heterogeneity in production technologies into account. This is not achievable, however, if only because of confidentiality regulations that have to be obeyed by statistical offices when compiling and publishing their data.

A second issue might well be even more critical, especially if employments effects for relatively small, open economies (such as the economy of the province of Groningen) are analyzed. In estimating such effects, we need to take into account that not all purchases will be sourced from local or even national suppliers. Some financial services used by a Groningen-based company might be supplied by banks in Amsterdam and electronic products bought by Dutch households are most probably imported from China or Japan. Such indirect and induced linkages do not cause further employment effects in Groningen (financial services industry) or the Netherlands (electronics industry), but do cause these in economies that do not belong to the scope of the analysis. With the widespread emergence of so-called "global value chains" in the first decade of the 21st century (Los et al., 2015), in which multinational enterprises split their production activities in many different stages and relocated several of these over locations where these can be performed at lowest costs, such leakage effects have become more sizable than before. This implies that the input-output tables used to compute the indirect and induced effects should allow for focusing on local or national effects with a high level of accuracy.

Which options were available to us, and which approach did we select with the issues discussed above in mind? For *The Netherlands as a whole*, the input-output table as published by Statistics Netherlands (het 'CBS') provides most industry detail. It splits the production sector into 81 industries, ranging from primary industries (agriculture, fishing, mineral extraction, etc.) to manufacturing industries and market and non-market services. This is the most detailed available input-output table for The Netherlands. In these tables, imported inputs have been recorded in a separate part, which provides opportunities to exclude the leakage effects mentioned previously. The most recent table that matches the employment data that are also needed is for 2017.

To compute the employment effects of NortH2 for the *Northern Netherlands* and for the province of *Groningen*, readily available data are less useful. Statistics Netherlands does not produce input-output tables at the regional level. The EUREGIO-database published by the PBL Netherlands Environmental Assessment Agency (see Thissen et al., 2018) is the only source of regional input-output tables available. It contains data for all twelve Dutch provinces, but only 14 industries are distinguished. Mineral exploration and power generation, for example, were merged into a single industry. Another downside is that the most recent year for which these tables are currently available is 2010, a decade ago. To circumvent these problems, we merged information from the detailed and recent national input-output table published by Statistics Netherlands for 2017 and the aggregated 2010 regional input-output table from EUREGIO, using techniques that have been widely accepted in the international community of input-output researchers (such as the "GRAS-procedure" proposed by Junius and Oosterhaven, 2003). We describe the procedure in detail in Appendix B. It is important to note that the 2017 input-output tables and employment numbers for the Northern Netherland and for Groningen are different from what Statistics Netherlands would obtain if it would construct regional input-output tables. The most important assumptions that we have to make relate to similarities between the production technologies of industries defined at the 81-industry level for Groningen, the Northern Netherlands and The Netherlands as a country. These similarities are most likely smaller than we had to assume (if only because company headquarters of large firms tend to be located disproportionally in the Western part of the country), but such assumptions are inevitable given the data situation. We do not expect that violations of these assumptions cause economically meaningful and systematic biases in the results reported below.

4. Estimated Employment Effects of the First Phase of NorthH2

The results of the estimations based on the input-out model discussed in the previous section and the scenarios presented in Section 2 are documented in Table 2 below.

Table 2a: Estimated employment effects in "maximum" scenario, in numbers of fulltime equivalent jobs (ftes, rounded to multiples of one hundred).

	Initial Investments			Maintenance and Asset Ownership		
	GR	N-NL	NL	GR	N-NL	NL
Wind farm	0	0	3600	100	200	200
Offshore	5000	5300	26400	200	200	300
Factory	5600	8500	14600	200	200	200
Transport	200	500	1600	500	800	1100
Storage	800	1200	2800	100	200	300
Total	*11700*	*15500*	*49000*	*1200*	*1600*	*2100*

Table 2b: Estimated employment effects in "minimum" scenario, in numbers of fulltime equivalent jobs (ftes, rounded to multiples of one hundred).

	Initial Investments			Maintenance and Asset Ownership		
	GR	N-NL	NL	GR	N-NL	NL
Wind farm	0	0	100	100	100	100
Offshore	3700	4000	4200	100	100	100
Factory	1200	4300	6900	200	200	200
Transport	100	300	1000	300	500	1000
Storage	400	900	2500	100	100	300
Totaal	*5500*	*9400*	*14600*	*700*	*1000*	*1700*

Notes: Estimates for Initial Investments fte-years; Estimates for Maintenance and Asset Ownership in ftes per year; Effects for the Northern Netherlands include effects in Groningen; Effects for The Netherlands include effects in the Northern Netherlands; Cells in columns do not always add up to the total, due to rounding.

If we first focus on the employment effects in the installation phase (the initial investments), we find that the total number of fte-years involved for the province of Groningen will most likely be in the range of 5 thousand to 12 thousand fte-years. For the three Northern provinces together, the effects will be a bit larger. For the Netherlands as a whole, the numbers of jobs involved will most likely be considerably higher, between 14 thousand and 50 thousand fte years. The relatively large differences between the North and The Netherlands is due to the fact that some specialized firms (especially related to the windfarm and the offshore power infra structure subprojects) are not located in the Northern provinces, but elsewhere in the Netherlands. According to experts, it is quite unlikely that such firms will set up shop in Groningen.

For the Netherlands as a whole, the difference between the "maximum" and "minimum" scenarios are much larger than for the North. The cause of these differences in magnitude is strongly related to the same issue. The windfarm, offshore power infrastructure and electrolyser factory together account for almost 90% of the initial investments. Some of the more basic tasks associated with these (related to security, installation work and basic construction activities, for example) will most probably be sourced from local or regional firms anyhow, irrespective of whether the suppliers of the products that require very specific knowledge and production capabilities are Dutch or not. For employment effects for The Netherlands as a whole, however, it is very important whether these very specific tasks will be performed by Dutch firms or not. An example is the production of the cables, a very sizable part of the initial investments in the offshore power infrastructure. In the Netherlands, only the factories of the former Nederlandse Kabel Fabriek (now owned by the Italian Prysmian Group) in Zuid-Holland can produce these cables. If the Prysmian Group would win the contract, the employment effects for Zuid-Holland would be considerable, but they would be close to zero if a firm without manufacturing facilities in The Netherlands would become responsible for the production and installation of the cables.

In the longer run, after the initial investment phase, NortH2 will most likely create about 1,000 fulltime jobs in the province of Groningen. For the three Northern provinces together, this number will be about 30% higher. For The Netherlands as a whole, the number of 'permanent' jobs associated with the project will be close to 2,000. The transport subproject is most important in this respect. Despite its small part of the initial investment costs (about 10% of these), the maintenance and repair of the pipeline structure and related equipment accounts for roughly half of the employment effects on all three geographical scales.

As discussed in Section 3, the results documented in Table 2 have been obtained using the semi-closed static input-output model, which incorporates direct, indirect and induced effects. In the context of this study, it is hard to quantify the magnitudes of the direct and indirect effects separately, which is due to the different levels of detail of information available for the subprojects. It is possible, however, to provide information on the relative importance of the induced effects. About 8% of the employment effects for Groningen are due to induced effects, for the Northern provinces together this share amounts to almost 9% and for The Netherlands as a whole, a share of about 16% is found. The differences between these shares are mainly due to households consuming part of their income on products from outside the region or country of interest. Dutch households spend more on products supplied by firms in The Netherlands, in comparison to what Groningen-based households spend on products supplied by Groningen-based firms. If a couple from Groningen spends part of its income on a weekend-trip to Maastricht, this yields additional employment in The Netherlands, but it does not for Groningen.

5. Implications and Conclusions

What do the results of this study imply for regional development in Groningen and the North of the Netherlands?

First, the short run employment effects differ between scenarios, but in the scenario in which regional firms win relatively large shares of contracts related to the construction and installation activities, the numbers of jobs are very substantial (about 15 thousand man-years in the three Northern provinces, of which close to 12 thousand in Groningen). For some of these jobs, it is likely that workers need to have very specific skills. Given the tight Dutch labor market, especially with regard to technical and ICT-skills, it will be hard to fill such vacancies with workers from the region. Schooling of unemployed workers in the region might be an option, but due to the relatively short period of employment in the initial phase of the project, investing in skilling workers is only beneficial if the acquired skills can also be used after the construction period. Hence, the potential long-term effect in terms of improving the skill level of the labor force in Groningen and the North is not very large. Still, NortH2 will help in reducing regional unemployment among lower-skilled people in the initial phase of the project, which will take multiple years. For the Netherlands as a whole, the employment effects during the initial stages of the project are strongly dependent on the question whether Dutch companies with very project-specific capabilities will win supplier contracts, or not.

The permanent effects, related to maintenance and asset ownership activities show less variation between the scenarios and the effects are also more concentrated in Groningen and in the North than for the initial investments. The number of jobs (700-1,200 for Groningen and 1,000-1,600 for the North) are substantial compared to e.g. the number of 2,300 fte that might be lost when the exploration and production of natural gas are discontinued (see Spisto et al., 2020). The long run importance of this number of jobs is particularly important if it creates jobs at the medium educational level (MBO), because in this segment unemployment is relatively high and more jobs might disappear due to continuing automation and robotization in virtually all sectors of the economy.

Another potential long run effect for regional development might occur if firms in the North would acquire unique expertise and knowledge, which it could export to other regions with H2 projects. Whether or not this effect will be present is very difficult to predict and thus very uncertain. This effect can be larger if the type of knowledge and necessary skills that are already available in the region can be used to create synergy and spillover effects if combined with the newly developed knowledge and skills. This can only happen if the existing and new knowledge are 'related', i.e., they are not too technologically distant from each other (see, e.g. Neffke et al., 2011). Given the strong focus on energy of the Northern Netherlands, this seems quite likely. The potential effects are also larger when the NorthH2 project is a frontrunner, because this makes it more likely that other regions that start later with H2-related activities will try to learn from the North. The more regions start with H2 at a later stage the higher the demand for this type of knowledge. However, if more regions start with H2 this might also lead to more competition if these regions invest in acquiring their own knowledge centers. Hence, it is important to create first-mover advantages and build on the existing position as energy region.

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Appendix A: The Semi-closed Static Input-Output Model

The study takes three kinds of employment effects into account. The direct effects relate to employment generated in the industries that deliver output directly to the project. These industries include the industry in which the companies that manage the project are operating. Indirect effects occur in industries that act as suppliers to the industries in which the direct effects take place. These can be "first tier" suppliers (selling themselves to industries contributing directly to the project), or "second tier" and "higher-order tier" suppliers, who only contribute indirectly to inputs into the project. Finally, the direct and indirect effects of large investment projects imply increased economic activity, which generate additional value added. Labor income, which is part of this value added, induces additional consumption by households, although they will spend this partly on imported products and most probably also save a bit. This additional consumption generates additional economic activity and employment. For value added other than labor income, such as corporate profits, the relationship is less clear: owners of firms can be located outside the region or abroad, and parts of profits can be retained. In the semi-closed static input-output model we use to estimate the employment effects of NorthH2, it is assumed that only labor income generates induced effects. The results presented in the report are the sum of the direct, indirect and induced effects of the investments associated with NortH2.

The computations are based on an input-output table and associated employment statistics. The details of the construction of such tables for (i) the province of Groningen, (ii) the three Northern provinces taken together and the source of the table for (iii) The Netherlands are documented in Appendix B. These tables all have the same structure, which is presented (in a stylized, simplified way) in Figure A1.

Figure A1: Stylized representation of an input-output table

		Use by industries				Final use			Total use
		Industry 1	Industry 2	…	Industry *n*	Consumption	Investment	Exports	
Supply by industries	Industry 1								
	Industry 2								
	…								
	Industry *n*								
Value added by labour									
Value added by capital									
Imports									
Gross output									

A row corresponding to an industry contains the value of its sales (in the year to which the input-output table refers) to each of the industries in the columns and to each of the final use categories (consumption, investment and exports). These cells in a row add up to the value of all sales by this industry, given in the column 'total use'. Consequently, a column for an industry provides information on the expenditures of this industry. It contains the values of purchases of intermediate inputs, such as materials, components and business services. These relate to intermediate inputs sourced from domestic industries only. Expenditures on imported intermediates are recorded in the 'imports' row. For the input-output tables for Groningen and for the Northern Netherlands, this row does not only capture purchases from abroad, but also purchases from other parts of The Netherlands. Besides intermediate products, industries also pay for the use of production factors, labor and capital. Compensations for these are recorded in the rows 'value added by labor' and 'value added by capital', respectively. The sum of all expenditures equals the values in the row 'gross output'. Double-entry bookkeeping conventions imply that the values of the cells in the 'gross output' row must be identical to those in the column 'total use'. Appendix B describes the methods we used to ensure that the regional input-output tables for this study are 'balanced' indeed.

The information contained in an input-output table can be used to estimate the effects of large investment projects on the output levels of each of the n industries represented in the table. To do so, we divide all entries in the nxn cells in the upper left block of the table (the part above and to the left of the double lines) by the entries in the bottom row ('gross output'). This yields an $(n+1)$x$(n+1)$ matrix with input coefficients, which we call $\mathbf{A}$. The element in row i and column j (element a_{ij}) gives the inputs (in euros) from industry i (or wage payments to households) per euro of output of industry j. The elements in the rightmost column of $\mathbf{A}$ are computed by dividing the consumption levels by total value added by labor.

In order to take all indirect and induced affects into account (a euro of car manufacturing output requires some cents of metal products, which require some cents of steel, which requires mining output, etc.), we use $\mathbf{A}$ to compute the matrix $(\mathbf{I}-\mathbf{A})^{-1}$. This matrix is known as the 'Leontief inverse' (named after Nobel laureate Wassily Leontief, the pioneer of input-output analysis). If we pre-multiply the Leontief inverse with a vector with employment coefficients (defined as the employment in an industry divided by its gross output), we find an $(n+1)$ vector with employment multipliers, $\mathbf{e}$. An element $\mathbf{e}_i$ gives the economy-wide employment effects of a euro of additional final demand (due to investment or export impulses) for the output of industry i. The $i+1$th element of $\mathbf{e}$ indicates the employment effect of an additional euro of labor income.

The scenarios described in Table 1 in the main text of the report led to quantifications of additional investment demand per product. If we compile these quantifications in an (nx1) vector $\mathbf{f}$, multiplying the row vector $\mathbf{e}$ and the column vector $\mathbf{f}$ yields the estimated employment effects documented in Table 2 of the main text. These include the direct, indirect and induced effects. The main text contains a discussion of the main assumptions behind the application of this model.

Appendix B: Construction of the 2017 Input-Output Table and Employment Statistics for Groningen and the Northern Netherlands

Data Sources:

1. European Interregional IO Table (2010). EUREGIO database (PBL): https://data.overheid.nl/dataset/pbl-euregio-database-2000-2010
2. National IO tables for the Netherlands at detailed sector level (2017, CBS): https://www.cbs.nl/en-gb/custom/2019/29/supply-and-use-input-output-and-sector-accounts
3. Production process and economic activities per region of the Netherlands (2017, CBS): https://opendata.cbs.nl/statline/#/CBS/en/dataset/84419ENG
4. Structural business statistics (SBS) by NUTS 2 regions and NACE Rev. 2 (2017, Eurostat)
   Product code: sbs_r_nuts06_r2

Step 1.
Construction of gross output and gross value-added for 81 detailed sectors in Groningen and the Northern Provinces

The CBS data of regional production and activities (Data 3) give information about output, value added and employment per province. However, economic activities in this database are classified into 21 sectors according the broad NACE category from A to U, which is less detailed than the 81-industry classification used in the Dutch national IO table (Data 2). Therefore, three different methods are used for estimating the gross output and value added per (detailed 81-) industry for Groningen and the North:

(i) In a few cases, a broad sector Data 3 is exactly the same as an industry in the Dutch National IO table. In this case the gross output and value added data are directly fetched from the CBS data.

In all other cases, a single broad sector in Data (3) corresponds to a few detailed industries in the input- output table. For example, the NACE broad sector of “Letter A: Agriculture” corresponds to three industries in the Dutch National IO Table, which are “1: Crop, animal production, hunting and related activities”, “2: Forestry and logging” and “3: Fishing and aquaculture”.
Since both Data 2 and Data 3 has information about the gross output and value added for The Netherlands as a whole, consistency checks between Data (2) and Data (3) are performed for these 1-to-N matches. It turned out that for all such cases, a broad sector in Data (2) corresponds perfectly to the summation of a number of detailed industries in Data (3). For these 1-to-N matches, depending on whether the detailed industries are covered in the Eurostat SBS data, two different methods are used:

(ii) The SBS data (Data 4) covers the detailed industries in manufacturing and market services (except finance-related services). For those detailed industries that can be found in the SBS dataset, the industry classification is the same as the Dutch IO table. The SBS data is available for the Netherlands at national, one-digit regional, and provincial level. The three Northern provinces (Groningen, Friesland and Drenthe) belong to the one-digit region of “Noord-Nederland”.

Although the SBS data at regional level do not disclose information about gross output and value added per industry, it does provide information on the salaries paid out by detailed industries in a region, which can be used to pinpoint the size of the sector in Groningen and in the Northern provinces. To do so, I assume that the ratios of salary to output and salary to value added are the same across regions in The Netherlands. Then the share of salary paid out in Groningen in an industry should be a good proxy for the output of Groningen in the Netherlands. For instance, assume that a detailed industry α paid out salary of 200 in Groningen while the total wage of it in the whole Netherlands is 500, then Groningen is predicted to have a share of 40% in industry α in The Netherlands. If then, according to the Dutch IO table (Data 3) the total output of α in the Netherlands is 2000 with value added as 1000, then it is predicted that the industry α in Groningen has output equal to 2000*40%=800, and value added of 1000*40%=400.

After doing so, a further balancing process is undertaken. Consider a broad sector X consisting of three detailed industries, α, β and γ. Data (3) has exact information about the gross output and value added from X in Groningen and the North, but the prediction from above steps for α, β and γ may not add up exactly to this number. Therefore, a balancing process is conducted and the predicted gross output (value-added) for the detailed industries are scaled making them adds up to the CBS data at broad sector level (Data 3). Consider for instance the output of α, β and γ of Groningen are predicted to be 800, 500, and 700, while Data 3 suggests the output of X in Groningen is 1800, then the predictions are scaled to be 90% and become 720, 450, and 630, respectively.

(iii) There is no information from Eurostat SBS (Data 4) for agriculture, non-market service sectors, and the financial service sectors. For these sectors, a stronger assumption has to be made, that is the structures of the industries within a broad sector in Groningen and in the Northern provinces are the same as the national structure.

That is, consider again a broad sector X with three detailed industries α, β and γ. Assume that Data (2) tell that the gross output (value added) of the three industries are 500, 300 and 200, and Data (3) tell that Groningen has an output (value added) of 100 in sector X. Then it is predicted that the output (value added) in Groningen are 50, 30 and 20 for the three detailed industries.

Construction of the Labor Costs and FTE Employment for 81 detailed sectors in Groningen and the Northern Provinces

The labor coefficients are estimated, primarily based on the Dutch National IO table (Data 2) and the production process and economic activities per region database (Data 3).

Data 3 provides information on labor costs (salaries, plus all kinds of labor-related social contributions) and FTE employment of 21 broad 1-letter NACE sectors for each province. A few of the 81 detailed industries correspond exactly to the 1-letter broad NACE sectors. For these cases, labor costs and FTEs are directly fetched from the CBS data. In other cases, one broad NACE sectors corresponds to a few industries, and the following strategy is used.

The Dutch National IO table also provides information on labor cost per industry in the Netherlands as a whole. Therefore, the share of labor costs in value added can be estimated for the Netherlands as a whole. Since the value added per detailed industry in Groningen (the Northern Provinces) has already been estimated in above, by assuming this share is the same in all provinces, one can infer the labor costs per detailed industry in Groningen (the Northern Provinces). The assumption that the labor share in value added is equal across all provinces should be reasonable. Summing over the above-estimated labor costs of the industries in Groningen and aggregating to the broad sectors, the summations are different with the actual labor cost per broad sectors in Groningen reported in Data 3, but the disparity is minimum for many of the broad sectors. Still, a balancing procedure like (ii) above is used and the estimates are scaled up or down, to ensure that when summing up to the broad sectors, the labor costs in Groningen (the Northern Provinces) are the same as reported in Data 3 by CBS.

To estimate the FTEs of employment in each detailed sector, it is assumed that the labor cost per FTE is the same across the detailed sectors if they belong to a same broad 1-letter NACE sector; the labor cost per FTE in broad sectors in Groningen (the Northern Provinces) can be directly calculated in Data 3.

Creating Input-Output Tables for Groningen and the Northern Provinces

The standard RAS updating procedure is used for creating the 81-sector input-output tables for Groningen and for the North. There are four elements needed: Gross output in Groningen (the North) which is obtained from the steps described above, intermediate input usage by each sector that are supplied by Groningen (the North), gross output sold as intermediate inputs to other Groningen (North) firms, and a technical matrix $A(0)$ used as the starting point of the RAS updating process. The last three items needs to be predicted.

The broad picture of the input-output structure of Groningen (the Northern Provinces) should resemble the Dutch national table. However, the input-output coefficients in the Groningen IO table represent the usage of intermediate inputs by Groningen's firm from the suppliers within Groningen, i.e. intermediate inputs purchased from other provinces should be excluded, since they are "leakage" from Groningen to other provinces. Moreover, the propensity of using imported intermediates should also differ across different regions in the Netherlands, for example as a consequence of geographical or infrastructural differences. In addition, production technologies of Groningen firms or the detailed industry composition of broad sectors in Groningen may be more different, for example due to the presence of natural gas fields.

Therefore, to construct the starting technical matrix of Groningen, $A(0)$, we take the value of the Dutch National Input-Output Table (Data 2) but then adjust for the difference in the likelihood of purchasing domestically (locally) using the information from the 2010 European Regional Input-Output Table (Data 1), assuming that these patterns did not change between 2010 and 2017.

Consider a typical element of B_{ij}^{CBS} in the input coefficients matrix derived from the Dutch national IO table, which represent the value of intermediate inputs from sector i from Dutch firms that are needed in producing one euro of gross output in a Dutch sector j.

To make the above mentioned adjustment, we define C_{ij}^{GR} as the input-output coefficient from the European Regional Input-Output Table, denoting the value of Groningen-produced intermediate *i* that are needed in producing one euro of gross output in the sector *j* in Groningen. The Dutch provinces in the European table can be also aggregated to produce the Dutch Input-Output Table in the year 2010, and the coefficient

$$C_{ij}^{NL} = \frac{\sum_{k,l \in NL} X_{(i,l)(j,k)}}{\sum_{k \in NL} y_{(j,k)}}$$

is the national input-output coefficient, indicating the value of intermediates from the sector *i* of all Dutch provinces in producing each euro of gross output of sector *j* in the Netherlands as a whole; $y_{(j,k)}$ denotes the gross output from sector *j* in province *k*, and $X_{(i,l)(j,k)}$ denote the total value of intermediate inputs produced by sector *i* in province *l* that is needed in producing these gross output. The starting value of $A(0)_{ij}$ for Groningen is therefore provided by

$$A(0)_{ij}^{GR} = B_{ij}^{CBS} \times \frac{C_{ij}^{GR}}{C_{ij}^{NL}}.$$

Note that the European regional IO table has a lower resolution and it classifies the economy into 14 sectors, while the Dutch national IO table 81 sectors. Except the "textile and leather" sector (which is the same in both tables), each of the other sectors in the European regional IO table corresponds to multiple entries in the Dutch table. Therefore, it is assumed that the ratio S_{ij} is the same for the detailed industries in the broader sector pair. For instance, consider the following hypothetical scenario. Our target is the value of intermediate inputs of cereal that is needed in producing one euro of beer from a Groningen beer brewery. The Dutch national IO table indicates that on average a Dutch brewery needs B_{ij}=0.1 euro of Dutch-made cereal in producing 1 euro of beer. The European IO table tells that for the Groningen firms in the broad food, drinks and tobacco ("FDT") sector, when it purchases agriculture ("AGR") inputs its (local) input-output coefficient is only 80% of the one for the Dutch national level (i.e. $C_{AGR,FDT}^{GR}/C_{AGR,FDT}^{NL} = 0.8$), then we predict the $A(0)_{ij}$ = 0.1*0.8 = 0.08 as the starting value for the RAS calibration.

The total intermediate inputs from Groningen that is needed to produce the gross output in each sector *j* is predicted by:

$$v_j = \sum_i y_j A(0)_{ij},$$

To execute the RAS algorithm, we still need to estimate the total gross output produced from each Groningen industry as sold to Groningen firms as their intermediate inputs. This is predicted in a similar way like the construction of the starting matrix *A*(0). From the Dutch National IO from CBS (Data 2) we observe the share of output from each Dutch industry used as intermediate inputs within the Netherlands ($Q_i^{CBS} = \sum_j X_{ij}/y_i$, where X_{ij} is the value of intermediate inputs produced by Dutch industry *i* and is used in Dutch industry *j*, and *j*, and y_i the Dutch output from industry *i*). From the 2010 European Regional Input-Output table (Data 1) we observe the share of output from (broad) sectors in Groningen that are used locally as intermediate inputs (denoted by R_i^{GR}), and by taking aggregation across all regions the same share of the Netherlands as a whole (denoted by R_i^{NL}). The ratio between the two can be again used as an adjusting factor for the share from CBS Dutch National IO Table of 2017. So the value of gross output from Groningen industry *i* used locally as intermediates is predicted to be

$$u_i = y_i \left(Q_i^{CBS} \times \frac{R_i^{GR}}{R_i^{NL}} \right).$$

Again, due to the fact that the European regional IO table has a lower resolution, it is assumed that the ratios R_i would be the same for all detailed industries within a broad sector.