Indicateurs de transition énergétique à l'échelle locale : approche basée sur l'étude du discours et cas d'application au Nunavik

par

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Indicateurs de transition énergétique à l'échelle locale :
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RÉSUMÉ

La transition énergétique fait l'objet d'un nombre d'études croissant, mais celles-ci n'en considèrent pas toutes la même définition. En effet, ce processus a priori technique s'articule aussi autour d'enjeux et de facteurs sociaux, économiques, culturels, politiques, ou environnementaux. De plus, l'étude de la transition est sensible au prisme spatio-temporel au travers duquel elle est analysée. L'évolution des systèmes sociotechniques diffère d'une région à l'autre, et ne se caractérise pas de la même façon selon l'échelle spatio-temporelle choisie. Les outils d'évaluation de la durabilité doivent ainsi prendre en compte l'aspect multidimensionnel de leur objet d'étude ainsi que son ancrage territorial et temporel. Si les séries d'indicateurs pluridisciplinaires présentent un tel potentiel, elles ne l'exploitent pas toutes. En fait, au moins cinq défauts sont communs à un grand nombre d'entre elles : ambiguïté définitionnelle, focalisation déséquilibrée des dimensions, manque de pertinence contextuelle, absence de participation des parties prenantes, et opacité méthodologique.

Pour répondre à ces enjeux, une nouvelle méthodologie visant à construire une série d'indicateurs est introduite. S'inspirant d'une méthode existante, elle propose une approche mixte quantitative-qualitative qui repose sur l'analyse textométrique du discours de presse. Elle vise à prendre indirectement en compte la perception des parties prenantes. Cet objet d'étude sert alors de base à la construction d'un cadre thématique structurant la démarche de sélection d'indicateurs. De plus, l'approche propose une analyse reposant sur un nouveau concept d'écho lexical caractérisant les interactions internes à ce cadre, mettant ainsi en valeur l'imbrication des dimensions entourant la transition énergétique. Par la suite, cette méthodologie est testée sur la région du Nunavik afin d'évaluer son efficacité et ses perspectives d'amélioration. Pour ce faire, un état des lieux de son système énergétique et de son contexte socio-économique est préalablement construit, de sorte à faciliter la prise en compte de ses caractéristiques spécifiques. Puis, la méthodologie est appliquée au Nunavik.

Un corpus de presse de 164 textes est alors concaténé, puis analysé. Il en résulte un cadre thématique structuré par huit classes thématiques primaires : « développement socio-économique durable », « énergie résidentielle et production décentralisée », « production d'énergie centralisée », « modes de vie face aux enjeux sociotechniques et environnementaux », « développement des énergies alternatives et le cas du projet hydroélectrique d'Inukjuak », « protection concertée de l'environnement », « changement climatique et biodiversité », et « aviation et fret aérien ». Ces dernières représentent les différentes dimensions des enjeux de la transition énergétique au Nunavik : énergétique, sociale, culturelle, politique, et environnementale. Ces huit classes sont ensuite décomposées en un total de 33 sous-classes thématiques plus précises.

Ensuite, seules les deux classes primaires les plus techniques « énergie résidentielle et production décentralisée » et « production d'énergie centralisée » sont complétées par des indicateurs, en raison de ressources limitées notamment. Il en découle une série de 28 indicateurs techniques, fournie avec des références guidant leur application. Cependant, la faible couverture statistique de la région du Nunavik est un frein à la finalisation de la série d'indicateurs, et à leur calcul. Cette application pourrait toutefois aider à construire une stratégie de collecte de données au Nunavik, et à participer à l'élaboration des futures politiques énergétiques nordiques. Finalement, quelques recommandations sont établies quant à l'usage futur de la méthodologie présentée afin de compenser ses limites, identifiées par cette première application. Il en ressort notamment qu'une implication directe de certains acteurs ou experts de la région serait utile et avantageuse.

Mots clés : transition énergétique, réseau autonome, Nunavik, autochtone, indicateurs, cadre conceptuel, étude du discours, IRaMuTeQ

Energy transition indicators at the local level:
an approach based on a study of discourse and case study in Nunavik

Robin CHAUBIER

ABSTRACT

The energy transition is the subject of a growing number of studies, but not all of them use the same definition. This a priori technical process also involves social, economic, cultural, political and environmental issues and factors. Furthermore, the study of transition is sensitive to the space-time prism through which it is analysed. The evolution of socio-technical systems differs from one region to another, and is not characterised in the same way depending on the spatio-temporal scale chosen. Sustainability assessment tools must therefore take into account the multidimensional aspect of their object of study, as well as its territorial and temporal anchorage. While multidisciplinary indicator series have such potential, not all of them exploit it. In fact, at least five shortcomings are common to a large number of them: definitional ambiguity, unbalanced focus on dimensions, lack of contextual relevance, lack of stakeholder participation, and methodological opacity.

To address these issues, a new methodology for constructing a series of indicators is introduced. Drawing on an existing method, it proposes a mixed quantitative-qualitative approach based on textometric analysis of press discourse. It aims to indirectly take into account the perception of stakeholders. This object of study then serves as the basis for the construction of a thematic framework structuring the indicator selection process. In addition, the approach proposes an analysis based on a new concept of lexical echo characterising the interactions within this framework, thus highlighting the interweaving of the dimensions surrounding the energy transition. The methodology is then tested in the Nunavik region to assess its effectiveness and prospects for improvement. To do this, an inventory of the region's energy system and socio-economic context is drawn up beforehand, to make it easier to take account of its specific characteristics. The methodology was then applied to Nunavik.

A press corpus of 164 texts was then concatenated and analysed. The result was a thematic framework structured around eight primary thematic classes: "sustainable socio-economic development", "residential energy and decentralised production", "centralised energy production", "lifestyles facing socio-technical and environmental challenges", "development of alternative energies and the case of the Inukjuak hydroelectric project", "concerted environmental protection", "climate change and biodiversity", and "aviation and air freight". These represent the various dimensions of the energy transition issues in Nunavik: energy, social, cultural, political and environmental. These eight classes are then broken down into a total of 33 more specific thematic sub-classes. Only the two most technical primary classes, "residential energy and decentralised production" and "centralised energy production", are supplemented by indicators, mainly because of limited resources.

The result is a series of 28 technical indicators, with references to guide their application. However, the poor statistical coverage of the Nunavik region is an obstacle to finalising the series of indicators and calculating them. This application could, however, help build a data collection strategy for Nunavik, and contribute to the development of future northern energy policies. Finally, a number of recommendations are made regarding the future use of the methodology presented in order to compensate for the limitations identified by this initial application. In particular, it is suggested that the direct involvement of certain stakeholders or experts in the region would be useful and advantageous.

Keywords : energy transition, autonomous grid, Nunavik, indigenous, indicator, conceptual framework, discourse study, IRaMuTeQ

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LISTE DES ABRÉVIATIONS, SIGLES ET ACRONYMES

AMC	Association minière du Canada
ARK	Administration régionale Kativik
CI	Commercial and institutional
CHD	Classification hiérarchique descendante
CQEK	Commission de la qualité de l’environnement Kativik
FCNQ	Fédération des coopératives du Nouveau-Québec
HCA	Hierarchical classification analysis
HQ	Hydro-Québec
HDQ	Hydro-Québec Distribution
IREQ	Institut de recherche en électricité du Québec
ISQ	Institut de la statistique du Québec
KEQC	Kativik environmental quality commission Kativik
KRG	Kativik regional government
KWREC	Kuujjuaraapik Whapmagoostui renewable energy corporation
Makivik	Makivik corporation / Société Makivik
MAMH	Ministère des Affaires municipales et de l’Habitation
NRC	Natural Ressources Canada
SHQ	Société d’habitation du Québec
WDH	Wind-diesel hybrid

LISTE DES SYMBOLES ET UNITÉS DE MESURE

UNITÉS GÉOMÉTRIQUES

Volume

L	litre

UNITÉS MÉCANIQUES

Énergie, travail, quantité de chaleur

kWh	kilowatt-heure
MWh	mégawatt-heure
GWh	gigawatt-heure
Toe	ton of oil equivalent

Puissance

kW	kilowatt
MW	mégawatt

Efficacité

kWh/L	kilowatt-heure par litre

UNITÉS D'ÉMISSIONS DE GES

Masse de CO_2 eq.

tCO_2 eq.	tonne de CO_2 équivalente
$kgCO_2$ eq.	kilogramme de CO_2 équivalent

Intensité de CO_2 eq.

$kgCO_2$ eq./kWh	kilogramme de CO_2 équivalent par kilowatt-heure
tCO_2 eq./year	tonne de CO_2 équivalente par an
tCO_2 eq./capita	tonne de CO_2 équivalente par habitant

INTRODUCTION

0.1 Origine du projet

Ce projet de maîtrise prend racine dans l'initiative ENERGON, un programme de recherche plus large et dédié à l'exploration de la question : en quoi les transitions énergétiques constituent un événement reconfigurateur des socioécosystèmes ?

Celui-ci s'appuie sur six territoires d'étude structurés par des contraintes fortes d'origine anthropique, les Observatoires Homme-Millieux (OHM). Quatre d'entre eux se situent en France, un aux États-Unis, et un dernier au Québec. Tous les six engagés dans une transition énergétique, ces sites de recherche constituent des laboratoires, offrant une opportunité d'explorer les transformations associées aux nouvelles politiques énergétiques. Plutôt que de cadrer la recherche par discipline, les OHM offrent une approche qui les transcende en mettant davantage l'accent sur les limites territoriales que sur les frontières disciplinaires. Ainsi, cette démarche favorise un dialogue entre les disciplines, leur permettant de partager un même espace, tant à l'intérieur de chaque OHM que dans une perspective interterritoriale. Cela permet de saisir la diversité des reconfigurations et de dépasser l'approche monothématique de manière exceptionnelle (Chenorkian, 2020).

Une des premières approches du programme ENERGON a été de vouloir construire une série d'indicateurs pluridisciplinaires apte à évaluer les transformations sur les territoires des OHM avant les projets de transition, pendant, et après. Éventuellement, cette série devait aussi permettre de comparer les OHM. Cependant, une méthodologie intégrée était nécessaire pour la construire sans biais de sélection et en intégrant la multidimensionnalité des processus de transition. Ce projet de maîtrise s'inscrit donc dans cette problématique. Plus précisément, la question de recherche guidant ce mémoire est la suivante :

Comment intégrer les sciences humaines et sociales à une méthode de sélection d'indicateurs permettant de caractériser la transition énergétique et ses spécificités spatiales tout en incluant son aspect multidimensionnel ?

0.2 Contexte

Parmi les six OHM, l'un couvre le territoire du Nunavik, la région la plus au nord du Québec, par-delà le 55^{e} parallèle. Ce territoire présente des caractéristiques socio-démographiques, culturelles, politiques, énergétiques et environnementales significativement différentes du reste du Québec. D'une part, il est principalement habité par des populations inuites et crie, les conditions sociales y sont moins favorables, et la gouvernance de la région lui est spécifique. D'autre part, le climat nordique y impose une contrainte énergétique plus forte, à un système déjà fragile et notamment dépendant des énergies fossiles. En fait, la région n'est pas connectée au réseau électrique intégré du Québec, et chaque communauté est alimentée par des systèmes de production d'électricité reposant sur le diesel. C'est en regard de cet OHM que le présent mémoire a été construit. En effet, cet espace d'étude a pu fournir le matériau suffisant à l'expérimentation de la méthode et à la poursuite des objectifs. Par ailleurs, dédier ce travail au Nunavik constitue un apport à l'étude de la transition en milieu nordique et isolé. Plus particulièrement, la région ne s'appuie pas encore sur des objectifs de transition clairement définis[1] et n'a pas de feuille de route officielle. De plus, elle souffre d'une couverture statistique relativement incomplète et une série d'indicateurs adéquate permettrait d'ouvrir la voie à un mécanisme de collecte de données.

0.3 Objectifs du mémoire et démarche

Afin de répondre au besoin du programme ENERGON et d'apporter de nouvelles perspectives d'analyse quant à l'état de la transition énergétique au Nunavik, l'objectif de ce mémoire a

[1] Dans une certaine mesure, seule la société Hydro-Québec a fixé des objectifs officieux de conversion des réseaux autonomes.

consisté à proposer et appliquer une méthode permettant de construire une série d'indicateurs de transition énergétique adaptée au contexte du Nunavik dépassant l'étude en silos disciplinaires. Il fut décomposé en deux objectifs : le premier étant théorique et généraliste, et le second étant appliqué au cas du Nunavik. La Figure 0.1 présente le cheminement logique qui a structuré le projet de recherche. Plus précisément, chacun des deux objectifs a mis en lumière plusieurs problèmes à outrepasser. Ainsi, cinq sous-objectifs ont pu être définis pour opérationnaliser l'atteinte des objectifs principaux et clarifier leurs interactions. La poursuite des sous-objectifs 1.1, 1.2, et 2.1 a mené à réaliser plusieurs revues de littérature. Quant aux sous-objectifs 1.3 et 2.2, ils constituent deux apports concrets de ce mémoire au champ d'études de la transition énergétique. Le premier sous-objectif consiste en une proposition méthodologique, et le second en une étude de cas utilisée comme test méthodologique.

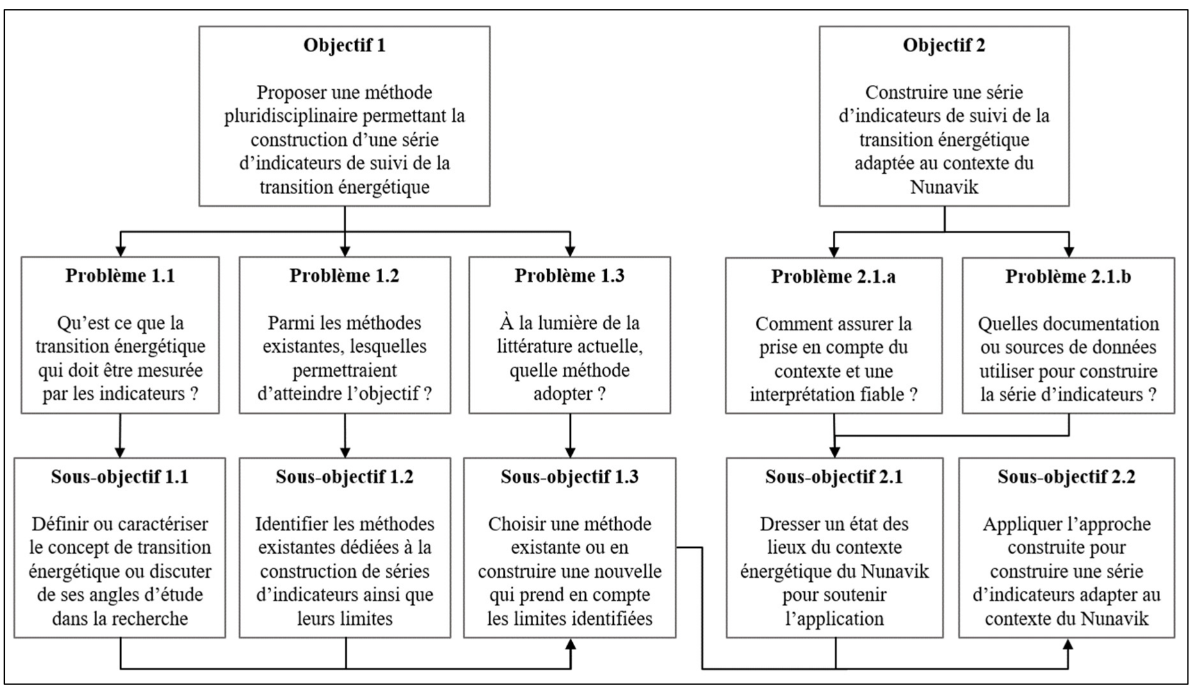

Figure 0.1 Objectifs du mémoire

0.4 Structure du mémoire

La structure de ce mémoire suit la même chronologie que la liste des sous-objectifs (Figure 0.2). En premier lieu, le chapitre 1 correspond à la revue de littérature du mémoire. Elle introduit une discussion sur les délimitations et implications de la transition énergétique dans le champ d'études qui lui est dédiée. Puis, un pont est fait entre ces constats et les méthodes de mesure, d'évaluation, et de modélisation de la transition avec une focalisation sur les séries d'indicateurs. En particulier, les limites des séries existantes et des pistes pour y faire face sont présentées. Dans un deuxième temps, une méthodologie générale est introduite par le chapitre 2, dans l'optique de combler certains manques identifiés dans la revue de littérature du chapitre 1. Celle-ci prend la forme d'un article soumis à une revue scientifique. Ensuite, le chapitre 3 constitue une étape préliminaire à l'application de la méthodologie. Il s'agit d'une revue de la littérature scientifique et de la littérature grise permettant de dresser un portrait de la situation énergétique du Nunavik, région à laquelle la méthodologie est appliquée dans le chapitre 4. Cette revue de littérature a également été soumise à une revue scientifique, car un manque de documentation synthétique à ce sujet manque à la littérature actuelle et limite les analyses macro-économiques de cette région. Ensuite, le chapitre 4 propose une application de la méthodologie définie dans le chapitre 2, de sorte à apporter des résultats partiels au Nunavik, mais aussi de mettre en perspectives les avantages et limites de l'approche. Enfin, des éléments de contexte entourant la participation autochtone et l'acceptabilité sociale des projets industriels ou énergétiques sont décrits en APPENDICE A.

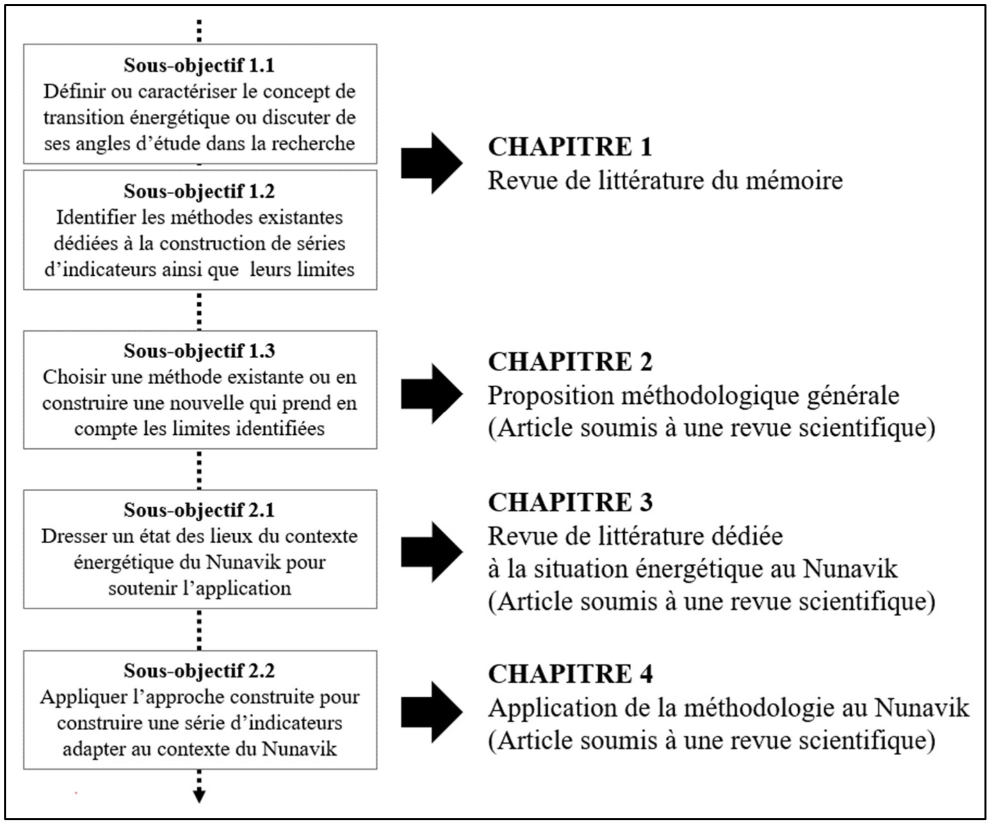

Figure 0.2 Structure du mémoire

CHAPITRE 1

REVUE DE LITTÉRATURE

La transition énergétique transcende les dimensions si bien que ses délimitations et implications restent floues. Ainsi, son évaluation dépend de la définition considérée du phénomène. Il convient donc de discuter de ses frontières et de ses composantes. Elle dépend aussi des outils et méthodes employées. L'usage d'une série d'indicateurs constitue une approche qui présente des avantages, bien que les applications existantes présentent des défauts récurrents. En particulier, l'absence d'implication des parties prenantes à la construction d'une telle série souligne les enjeux de représentation et d'appropriation associés. Il est ainsi nécessaire d'explorer les méthodes de participation et d'engagement existantes.

1.1 Définitions et délimitations de la transition : un cahier des charges pour savoir quoi mesurer

1.1.1 Multidimensionnalité de la transition

La définition des transitions énergétiques et la façon de les étudier sont des sujets largement discutés dans la littérature. Fortin et al. (2016) les décrivent comme une réorganisation des relations entre des systèmes « sociaux, économiques, techniques et naturels ». Dans ce sens, Sovacool & Geels (2016) les présentent comme des processus multidimensionnels qui transforment des systèmes d'acteurs et font intervenir des interactions multiples entre ces derniers. Ces deux auteurs rappellent d'ailleurs le triptyque proposé par Geels (2004). Les transitions reposeraient sur trois dimensions : « les éléments tangibles des systèmes sociotechniques », « les acteurs et les réseaux sociaux », et « les régimes sociotechniques ». Plus concrètement, la première englobe par exemple les technologies, les infrastructures, et les logistiques d'approvisionnement. La seconde inclut le comportement des acteurs, notamment sur le plan économique, puis la troisième intègre les réglementations et les normes sociales. Ce découpage permet de proposer une démonstration non exhaustive de la multidimensionnalité des transitions.

Premièrement, les transitions se matérialisent par une transformation des systèmes énergétiques. Celle-ci vise en partie à faire face à l'épuisement des énergies fossiles (Mediavilla et al., 2013; Miller & Sorrell, 2014; Tverberg, 2012), ainsi qu'à limiter les conséquences environnementales associées à leur usage, celles-ci ne se limitant pas seulement au changement climatique : acidification des océans, charge atmosphérique en aérosols, etc. (Rockström et al., 2009; Salari et al., 2021; Wang-Erlandsson et al., 2022). Pour ce faire, une diversification des sources d'énergie vers davantage de sources indigènes et renouvelables est nécessaire afin de garantir un approvisionnement énergétique durable et de réduire les émissions de GES anthropogéniques (Kjärstad & Johnsson, 2009; Mohsin et al., 2018; Salari et al., 2021). Ainsi, de nombreuses analyses technico-économiques sont menées sur les systèmes en transition, à des échelles internationales, nationales, voire régionales (Chen et al., 2019; Jianchao et al., 2021; Stringer & Joanis, 2022). Cet aspect constitue en effet une part fondamentale de l'étude des transitions, mais ne lui est pas exclusif, car des perspectives sociotechniques et politiques s'y adjoignent (Cherp et al., 2018a).

En effet, la transition énergétique comprend deuxièmement une dimension sociale qui repose notamment sur ses interrelations avec le plan technique. Ils se conditionnent mutuellement, formant alors un système sociotechnique (Miller et al., 2013). Ainsi, la transformation d'un système énergétique induit inexorablement une transformation sociale, pouvant d'ailleurs mener à des conflits (Miller & Richter, 2014). Si cet aspect sociotechnique est étudié en tant que système à modéliser (Krumm et al., 2022; Omri et al., 2022), il est aussi largement étudié sous l'angle de la justice énergétique. En effet, le processus de transition peut engendrer des inégalités sociales, bien que leur répartition dépende principalement de la situation socio-économique initiale des individus (Carley & Konisky, 2020; S. Meyer et al., 2015; von Platten et al., 2020). Pour cause, la transformation des systèmes ne se fait pas forcément en considération institutionnelle ou politique de la justice énergétique ou de la précarité énergétique (Lampis et al., 2022).

Plus généralement, le processus de transition est lié à une dimension humaine, comportementale, et culturelle qui doit être prise en compte pour planifier et favoriser l'acceptation des politiques énergétiques (Maresca & Dujin, 2014). En effet, la transition énergétique dépend d'une morphose du mode vie non planifiée, et donc d'une remise en cause des normes sociales (Steg et al., 2015; van der Kam et al., 2018). Dans ce sens, la complexité des transitions européennes est analysée par Sarrica et al. (2016) au travers d'une approche culturelle. En effet, la culture joue un rôle global dans les transitions et elle peut être un vecteur méconnu de progrès comme d'obstacles (Sovacool & Griffiths, 2020). Ainsi, une vision socioculturelle de la transition énergétique et de l'ère des énergies renouvelables faciliterait le choix d'un avenir énergétique désirable (Ruotsalainen et al., 2017). Par ailleurs, les attitudes sociétales constituent un pilier des sphères réglementaires, politiques, et de gouvernance qui aiguillent les transitions. Le second pilier est l'action politique (Hainsch et al., 2022). En effet, des politiques constantes et harmonieuses sont essentielles pour initier une nouvelle transition énergétique (Grubler, 2012). Finalement, cette interaction entre culture et politique introduit la dernière branche du triptyque de Geels (2004) considérant les normes réglementaires et sociales.

Dans tous les cas, les transitions, qu'elle soit « énergétique », « écologique », ou « agro-alimentaire », ont des répercussions diverses sur les territoires. En effet, elles peuvent créer de nouveaux espaces de production, entraîner des reconfigurations socio-économiques, et transformer un système d'acteurs (Deshaies, 2021; Mattes et al., 2015). Or, beaucoup d'études en lien avec l'énergie ont tendance à se restreindre à un seul secteur, ou à une seule dimension, souvent technique ou économique. De plus, certaines se limitent à l'étude des régions développées. Ainsi, une définition restreinte de l'objet d'étude ainsi que l'absence de multidimensionnalité constituent souvent une faiblesse parmi les études de la transition énergétique (Sovacool, 2013). En effet, une approche multidimensionnelle permet de produire des analyses robustes et non biaisées par la prévalence d'une unique dimension. Elle permet aussi de s'assurer qu'un objectif de transition ne met pas en compétition plusieurs dimensions, ou à l'inverse de lui découvrir des co-bénéfices (Naegler et al., 2021; Omri et al., 2022). Par exemple, une étude abordant le déploiement de l'énergie éolienne au Saskatchewan a montré que l'analyse isolée de facteurs unidimensionnels ne permettait pas d'identifier les freins à la transition, ce qu'a permis une approche intégrée (Richards et al., 2012). Cependant, les approches multidimensionnelles peuvent être limitées par les différences fondamentales entre certaines dimensions qui ne peuvent pas être décrites de la même façon. S'il est alors possible de procéder à des approximations pour construire des méthodes multifacettes intégrées, Geels et al. (2016) suggèrent plutôt de faire le pont entre les dimensions.

En somme, les processus de transition infiltrent toutes les dimensions, et leur prise en compte dans une démarche holistique apporte de meilleures clés de compréhension. Cependant, elles dépendant de deux autres facteurs : l'espace et le temps.

1.1.2 Transition à géométrie variable : échelles spatio-temporelles et approches situées

À différents égards, l'innovation technologique fait partie de la transition et des leviers d'action nécessaires pour la réussir (Araújo, 2014; Grubler, 2012), mais les technologies sont variées et les enjeux diffèrent d'une région à l'autre. En particulier, les trajectoires dépendent de facteurs divers dont le système énergétique hérité (Guidolin & Guseo, 2016; Palit & Bandyopadhyay, 2016), le niveau de développement (Elias & Victor, 2005), ou les conditions naturelles imposant des contraintes énergétiques (Cherniak et al., 2015; Maranghi et al., 2023; Pawluk et al., 2019). Ainsi, les transitions énergétiques peuvent suivre différents chemins. Par exemple, l'échelle globale opère une addition énergétique plutôt qu'une transition (York & Bell, 2019) tandis que l'Amérique du Sud réalise une diversification énergétique (Lampis et al., 2022) et que seules l'Europe et l'Amérique du Nord présentent une tendance de décarbonation modérée accompagnée d'une légère baisse de consommation (Lamb et al., 2021). Si les méthodes et défis peuvent différer d'un pays à l'autre, y compris entre pays voisins (Laes et al., 2014), elles sont aussi contrastées à des échelles inférieures, au niveau régional notamment (Hoppe & Miedema, 2020). Les différentes provinces canadiennes en sont un exemple puisque la production d'électricité y est de compétence provinciale (Stringer & Joanis, 2023) et les régions nordiques du Canada constituent des cas particuliers supplémentaires (Cherniak et al., 2015). Ainsi, même en restreignant la transition énergétique à sa dimension technique, la question des échelles spatiales intervient dans les enjeux et modes opératoires.

Ces contrastes spatiaux impliquent une gestion à plusieurs échelles. D'abord, la transition énergétique peut être pilotée et étudiée à une échelle continentale et fortement impliquer la coopération internationale. C'est ce que montre le cas du Green Deal européen (Hainsch et al., 2022). Cependant, son opérationnalisation s'opère à des échelles inférieures, à commencer par des échelles subcontinentales, ou nationales (Siksnelyte et al., 2019). De plus, l'aspect régional des transitions est largement décrit par Coenen et al. (2021). Plus encore, elle peut être étudiée à une échelle locale, voire communautaire (Mundaca et al., 2018). Dans ce sens, l'importance d'un regard porté sur la transition à des échelles locale et régionale est mise en avant par Mattes et al. (2015). Son travail montre qu'à ces échelles, les transitions sont influencées par des acteurs individuels, organisationnels et institutionnels qui participent à la gouvernance énergétique. De plus, l'échelle locale, et particulièrement dans les régions isolées, permet la prise en compte de facteurs sociaux aptes à favoriser le succès des projets de transition. En effet, ces facteurs mettent en lumière les freins à leur mise en place et favorisent les démarches de co-construction (Montedonico et al., 2018).

Ainsi, la tendance globale ou occidentale de la transition énergétique n'adresse pas forcément les problématiques énergétiques de toutes les régions. La réalité des transitions dépend du contexte sociotechnique, ce qu'une approche « située » permet de capturer (Cline-Cole & Maconachie, 2016). En particulier, la définition théorique des transitions portée par les organisations internationales serait déconnectée des réalités des pays du sud (P. Robert, 2021b). Par ailleurs, la multiplicité des acteurs et intérêts impliqués dans les transitions mène au développement de contextes technologiques et de gouvernance spécifiques à des espaces locaux (Fuchs & Hinderer, 2014). Plus généralement, un manque de considération est appliqué à la dimension géographique des transitions. Dans ce sens, le concept de « milieu valuateur » est par exemple proposé pour intégrer leur aspect territorial et explorer leurs interactions multidimensionnelles internes, entre valeurs économiques, valeurs culturelles et environnementales (Huguenin, 2017). Plus encore, Glück (2018) discute de l'approche situationnelle qui serait un niveau d'analyse pertinent pour prendre en compte la complexité des systèmes sociotechniques, et notamment les aspects culturels associés.

À différents égards, les approches ancrées dans le contexte montrent effectivement leur nécessité ou leur efficacité. D'une part, certains phénomènes doivent être étudiés selon des échelles spatio-temporelles situées. C'est le cas par exemple de la précarité énergétique qui dépend de facteurs régionaux en Europe (Bouzarovski & Tirado Herrero, 2017). D'autre part, les analyses situées se montrent utiles et efficaces pour traiter des problématiques spécifiques. Par exemple, cette approche permet à Meyer (2021) de caractériser l'emprise spatiale de deux centrales nucléaires en France et en Allemagne. Par ailleurs, le cas d'une étude territorialisée réalisée en Saskatchewan permet de brosser un portrait multidimensionnel des perspectives du développement des énergies renouvelables dans cette province (Nwanekezie et al., 2022).

En conclusion, l'étude des transitions énergétiques nécessite des approches analytiques multidimensionnelles et ancrées dans un contexte spatio-temporel. Cependant, cela constitue un défi pour les méthodes de modélisation et d'évaluation.

1.2 Évaluation et suivi de la transition : un défi multi-dimensionnel

1.2.1 Nécessité d'évaluer et d'identifier les dynamiques

Depuis les années 1990, les travaux entourant la définition et l'évaluation de la durabilité sont nombreux. Ainsi, une diversité d'approches et d'outils a été proposée pour évaluer la durabilité d'une région (Doukas et al., 2012). Cette évaluation montre son utilité dans sa capacité à répondre à plusieurs besoins. Notamment, Waas et al. (2014) expliquent qu'elle fait écho à trois défis : un défi d'interprétation, un défi de structuration de l'information, et un défi d'influence. En effet, elle contribue à une meilleure compréhension de ce que sont la durabilité et son interprétation contextuelle. De plus, elle identifie les problèmes, mesure les impacts et structure l'information, ce qui permet d'intégrer les problématiques de durabilité à la prise de décision. Plus largement encore, elle aide à promouvoir les objectifs de durabilité. Ainsi, elle ne joue pas simplement un rôle de « action-guiding », mais aussi celui de « action-generating » (Waas et al., 2014). Par ailleurs, l'évaluation participe au suivi et à la construction de trajectoires de transition permettant de fixer des objectifs et de planifier les mesures à mettre en place en faveur de leur atteinte. Entre autres bénéfices, cela ouvre notamment la voie à des débats de société éclairés par les futurs envisageables (Grunwald, 2011).

1.2.2 Modélisation et méthodes d'évaluation

Ness et al. (2007) présentent une synthèse des outils d'évaluation de la durabilité et suggèrent la classification illustrée par la Figure 1.1. Celle-ci catégorise les approches selon leur focus temporel, d'un usage relativement rétrospectif à davantage prospectif.

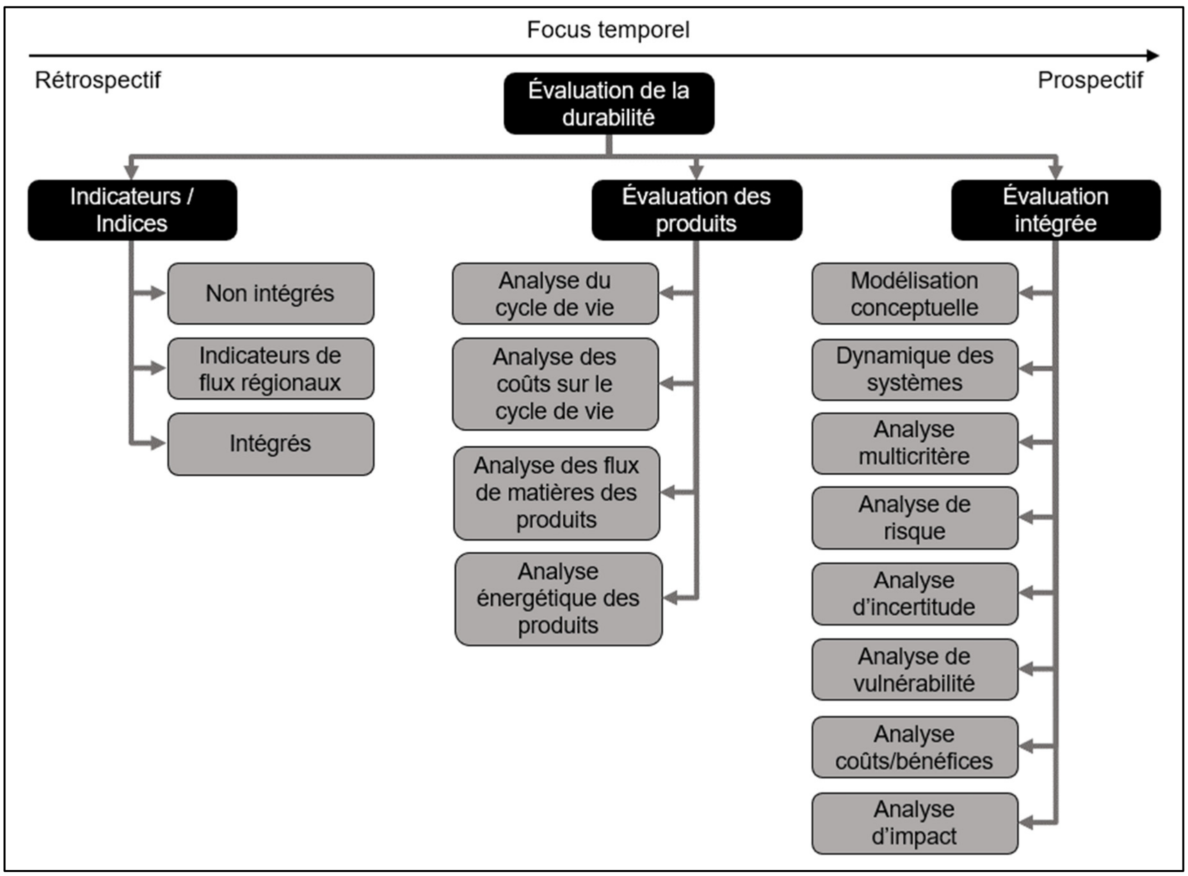

Figure 1.1 Répertoire des outils d'évaluation de la durabilité
Adaptée de Ness et al. (2007)

Au centre sont regroupés les outils liés aux produits, qui peuvent être utilisés selon ces deux temporalités. Ils se concentrent sur les flux liés à la production et à la consommation de biens et de services. Ils évaluent l'utilisation des ressources et les impacts environnementaux le long de la chaîne de production ou tout au long du cycle de vie d'un produit. Généralement, ces outils n'intègrent pas les aspects « nature et société »[2], bien que des approches incluant d'autres dimensions - notamment la sphère sociale - aient émergé (Lagarde & Macombe, 2013; Ramirez et al., 2014).

Sous un angle prospectif, la modélisation conceptuelle et la dynamique des systèmes sont des approches répandues pour l'évaluation de la durabilité. Cependant, elles se sont surtout développées sur le plan technique, dans l'optique d'évaluer la façon dont les systèmes énergétiques pourraient répondre aux contraintes futures (Chang et al., 2021; Sánchez Diéguez et al., 2022). Plus largement, les modélisations technico-économiques constituent un champ d'études actif (Crespo del Granado et al., 2018; Rye & Jackson, 2018). Cependant, relativement peu d'études intègrent en profondeur les dynamiques sociétales et sociopolitiques à la modélisation. Il s'agit là d'un vide à combler qui est de plus en plus discuté et qui suscite des propositions méthodologiques (Li et al., 2015). Par exemple, Cherp et al. (2018) proposent un cadre mettant en parallèle les dimensions techno-économiques, sociotechniques et politiques, chacune étant reliée aux deux autres. En effet, l'élargissement des méthodes aurait plusieurs bénéfices et permettrait de répondre à davantage de questions (Bolwig et al., 2019; Spurlock et al., 2022). Cependant, des efforts interdisciplinaires sont nécessaires pour formaliser les interactions entre les dimensions (Geels et al., 2016; Trutnevyte et al., 2019).

À des échelles souvent moindres, dans le cadre de l'étude d'un objet focal réduit, l'analyse multicritère constitue un outil d'aide à la décision qui emploie un cadre méthodologique comparativement plus simple. Typiquement, elle est utilisée pour évaluer ou comparer des projets, impliquant par exemple un choix entre plusieurs solutions techniques (Yan et al., 2019). Elle présente l'avantage de pouvoir inclure plusieurs dimensions, dont l'intégration repose alors sur les critères choisis pour la définir (Ness et al., 2007; Singh et al., 2022).

[2] Cette expression fait référence à la multidimensionnalité des problématiques de durabilité.

Par ailleurs, ce type d'analyse peut aussi s'appliquer à l'étude du milieu social et à la perception des acteurs socio-économiques (Paquet et al., 2021). Éventuellement, l'analyse multicritère peut servir à des analyses et comparaisons internationales (Neofytou et al., 2020). Cependant, ce type d'outil reste principalement appliqué à des échelles temporelles et à des objets d'étude restreints. De plus, il apporte davantage une image instantanée des situations qu'il ne permet un suivi de long terme.

Finalement, la dernière catégorie d'outils d'évaluation de la durabilité présentée par Ness et al. (2007) comprend les indicateurs et les indices[3]. Lorsqu'ils sont mesurés et calculés en continu, ils permettent de suivre les tendances de durabilité à long terme dans une perspective rétrospective. Comprendre ces tendances permet de faire des projections à court terme et de prendre des décisions pertinentes pour l'avenir. Les outils basés sur l'utilisation d'indicateurs et indices peuvent intégrer les paramètres « nature et société », bien que ce ne soit pas systématiquement le cas (Ness et al., 2007).

1.2.3 Définition, utilité, classification et limites des indicateurs

Un indicateur peut être défini comme la « mesure d'un objectif à atteindre, d'une ressource mobilisée, d'un effet obtenu, d'un élément de qualité ou d'une variable du contexte » (De Amorim et al., 2005). Cependant, leur définition repose généralement davantage sur le rôle qu'ils jouent. Les indicateurs sont des mesures simples, généralement quantitatives, qui représentent par exemple un état de développement économique, social ou environnemental dans une région définie, souvent au niveau national (Ness et al., 2007). Ils permettent de simplifier une réalité complexe en donnant une information concernant la problématique qu'ils traitent (European Environment Agency (EEA), 1999). Ce rôle de simplification leur permet d'être des outils de communication efficaces quant à des problématiques spécifiques, bien qu'ils soient des réductions de la réalité, et doivent être considérés comme tels (Waas et al.,

[3] Ces derniers sont obtenus en agrégeant des indicateurs d'une certaine manière.

2014). Ainsi, ils sont de plus en plus reconnus comme des outils utiles à l'élaboration des politiques et à la communication publique (Singh et al., 2012). En effet, ils jouent un rôle de soutien à la caractérisation des problèmes, à l'établissement des priorités, à la formulation des politiques, et à l'évaluation de leurs effets (Adelle & Pallemaerts, 2009; EEA, 1999; Farsari & Prastacos, 2002). Parfois, ils permettent aussi d'identifier des vides statistiques et contribuent alors à un cadre de collecte de données (Farsari & Prastacos, 2002). Éventuellement, ils peuvent servir à comparer des régions ou pays et à produire des classements. Ils constituent alors des outils d'influence qui contribuent de manière significative à l'élaboration des politiques. En effet, ils mettent en avant les « success stories » ainsi que des références auxquelles se comparer, aidant ainsi au tracé des chemins de transition (Neofytou et al., 2020).

Ness et al. (2007) soulignent que les « indicateurs et indices intégrés » sont susceptibles de prendre en compte les aspects « nature et société », car ils sont utilisés sous la forme de séries d'indicateurs, ou d'indices agrégés sur la base de plusieurs indicateurs. En effet, des indicateurs utilisés individuellement ne constituent qu'une vue réduite et unidimensionnelle (Doukas et al., 2012; Iddrisu & Bhattacharyya, 2015; Martchamadol & Kumar, 2013; Siksnelyte et al., 2019). Cependant, Narula & Reddy (2015) discutent de la pertinence des indices agrégés. En particulier, chacun est construit différemment, considérant la sélection des indicateurs et la méthode d'agrégation employée. Ainsi, plusieurs indices censés mesurer le même concept peuvent donner des indications différentes. De plus, les indices ont une moindre interprétabilité que les indicateurs initiaux sur lesquels ils sont construits. En effet, ils sont davantage associés à un concept tandis que les indicateurs initiaux mesurent quelque chose de plus concret. D'ailleurs, certains indicateurs individuels non agrégés sont des outils phares pour informer et alerter le grand public. Les rendre accessibles est donc un enjeu de communication (Hák et al., 2016). En somme, bien que les indices aient des avantages, les séries d'indicateurs présentent moins de limites d'interprétation (Narula & Reddy, 2015).

Si les indicateurs peuvent être classés selon la dimension ou la thématique qu'ils évaluent, ou en fonction du cadre conceptuel auquel ils appartiennent (Waas et al., 2014), plusieurs découpages co-existent pour classifier les différents types d'indicateurs. L'Agence Européenne de l'Environnement (European Environment Agency (EEA), 1999) propose par exemple une classification en quatre groupes qui répondent chacune à une question :

- Indicateurs descriptifs : « Qu'arrive-t-il à l'environnement et à l'homme ? » ;
- Indicateurs de performance « Est-ce important ?" » ;
- Indicateurs d'efficacité : « Nous améliorons-nous ?" » ;
- Indicateurs de bien-être global « Sommes-nous globalement mieux lotis ?" ».

Cependant, nombre de classifications existent et se chevauchent, rendant difficile le choix d'une classification plutôt qu'une autre. Par exemple, Waas et al. (2014) présentent une dichotomie opposant des couples de catégories : indicateurs descriptifs et normatifs, quantitatifs et qualitatifs, ex-ante et ex-post, objectifs et subjectifs, ou encore basés sur la communauté ou sur les experts. D'autres exemples existent dans la littérature scientifique (Iddrisu & Bhattacharyya, 2015), mais les institutions sont aussi forces de proposition (Commission européenne (CE), 2006b, 2006a; De Amorim et al., 2005). Cependant, nombre de classifications ne sont pas utilisées, parfois au profit de cadres plus simples tels que la classification thématique de Adelle & Pallemaerts (2009).

1.3 Série d'indicateurs

Le quarantième et dernier chapitre de l'Agenda 21 fut consacré aux outils de prise de décision. Il appela au développement d'indicateurs capables d'évaluer - à des échelles locales, régionales, nationales, ou internationales - le statut et les évolutions des différentes variables caractérisant les écosystèmes, les ressources, la pollution, et les activités socio-économiques. Par ailleurs, il recommanda de combler le manque de capacité à récolter des données (UNCED, 1992). La nécessité d'opérationnaliser les processus menant jusqu'à la durabilité résulta ainsi au développement d'indicateurs environnementaux et socioculturels, en plus des traditionnels indicateurs économiques (Farsari & Prastacos, 2002). Dans les années et décennies suivantes, plusieurs organisations et agences proposèrent donc des séries d'indicateurs aptes à suivre l'évolution du progrès, en tout ou partie (Gunnarsdóttir et al., 2020; Khan et al., 2000; I. A. Vera et al., 2005).

1.3.1 Introduction à l’analyse du discours

L’étude du discours - ou analyse discursive - consiste en une méthode d’analyse de la langue, du vocabulaire, et de leurs usages spécifiques, permettant d’identifier des sujets et les intervenants qui en parlent. Cette approche vise à établir une sorte de carte des thèmes abordés et des types d'arguments échangés, sans nécessairement entrer dans les détails d'une analyse approfondie des modes de raisonnement de chaque participant. En somme, cette approche permet de répertorier les arguments en jeu dans un cadre donné (Charaudeau, cité dans Delormas, 2015). Les approches discursives sont de plus en plus utilisées dans l’analyse des systèmes sociotechniques, et plus précisément, dans le cadre des processus de transition et des politiques énergétiques qui s’y adjoignent. Plus précisément, elles ont été principalement utilisées pour analyser les changements institutionnels et les stratégies politiques au niveau national, ainsi que pour examiner les choix énergétiques et les perceptions du public. Ainsi, les méthodologies discursives permettent aux chercheurs d'enrichir les discussions politiques en tenant compte des transitions en tant que processus complexes et dynamiques (Isoaho & Karhunmaa, 2019).

Plus particulièrement, l’analyse du discours peut servir à fournir un portrait des acteurs participant au processus de transition et décrire la façon dont ils la perçoivent (Krzywda et al., 2021). Par exemple, Walker et al. (2018) étudient les discours politiques des parties prenantes entourant la technologie éolienne au Canada. Sur la base d’une méthode mixte - qualitative et quantitative - reposant sur des entrevues semi-directives et des questionnaires, cette étude souligne l’implication du contexte politique dans l’acceptation des projets éoliens. De plus, d’autres liens complexes peuvent être investigués par cette approche. Par exemple, l’évolution des discours en lien avec la transition énergétique peut être analysée comme le reflet - entre autres - des carbon lock-in, ou des points d’inflexion, accélérant ou ralentissant la transition. Le récent cas d’étude du système allemand illustre les perspectives d’analyse majeures de cette approche (Buschmann & Oels, 2019). Dans une autre dimension, elle permet d’explorer des problématiques socioculturelles et historiques profondes, en particulier dans le contexte canadien, en lien avec les populations autochtones. Dans ce sens, une étude explore les thématiques de décolonisation et de réconciliation associées au déploiement des énergies renouvelables. Au travers d'entretiens, les perceptions de partenaires non autochtones sont analysées et il apparaît que le manque d'exposition à l'histoire autochtone affecte leur engagement avec la réconciliation (Walker et al., 2021).

1.3.2 Critique des séries existantes

Malgré plusieurs décennies de développement, le domaine d'étude scientifique et institutionnel dédié au développement de séries d'indicateurs ne bénéficie pas d'une théorie universelle établie, bien que plusieurs institutions et groupes de chercheurs s'accordent sur quelques points. En particulier, Gunnarsdóttir et al. (2020) rapportent qu'au moins cinq défauts caractérisent couramment les séries d'indicateurs existantes : une ambiguïté de définition, une focalisation déséquilibrée, un manque de pertinence contextuelle, l'absence de participation des parties prenantes, et une opacité méthodologique (Shortall & Davidsdottir, 2017).

1.3.2.1 Problème 1 : ambiguïtés définitionnelles

En effet, nombre de séries existantes présentent des **ambiguïtés définitionnelles,** car aucune définition du « développement durable de l'énergie » (DDE) - et par extension de la transition énergétique - n'est universellement reconnue. Or, la diversité des parties prenantes et des contextes peut mener à interpréter et hiérarchiser différemment les aspects de la durabilité. Cette ambiguïté a des conséquences sur les indicateurs utilisés, ce qui peut influencer, voire limiter, les interprétations des situations énergétiques et les comparaisons entre pays ou entre systèmes (Gunnarsdóttir et al., 2020; Shortall & Davidsdottir, 2017). Ainsi, certaines séries intègrent des axes spécifiques, et peuvent s'y restreindre, ou considèrent seulement l'étude d'un seul objet focal tel qu'un thème spécifique, une dimension ou une discipline, un secteur, ou encore un enjeu précis (Sovacool, 2013).

Le cas de la sécurité énergétique est emblématique, car il est le thème principal d'un quart des séries en lien avec le DDE (Gunnarsdóttir et al., 2020) et il est lui-même l'objet d'une ambiguïté définitionnelle. En effet, il n'est pas toujours traité de la même façon, et repose parfois sur des définitions partielles, voire contradictoires. En particulier, son aspect social est parfois omis (Sovacool, 2013). De même façon, le thème de l'efficacité énergétique est souvent naturellement abordé dans les séries (Iddrisu & Bhattacharyya, 2015; International Atomic Energy Agency (IAEA) et al., 2005; Streimikiene & Šivickas, 2008). D'ailleurs, de larges séries dédiées sont proposées par certaines institutions (IEA, 2014; ODYSSEE-MURE, 2020; OECD, 2022) et des applications visant certains secteurs, en particulier l'industrie et le secteur résidentiel apparaissent dans la littérature (Abu Bakar et al., 2015; Dibene-Arriola et al., 2021; Franco et al., 2023; Gielen & Taylor, 2009). Cependant, il n'est pas toujours défini par les mêmes problématiques sous-jacentes : efficacité de la distribution, efficacité de la conversion, intensité énergétique, intensité carbone, efficacité globale, etc.

1.3.2.2 Problème 2 : focalisation déséquilibrée

Certains indicateurs ont tendance à mettre l'accent sur des dimensions spécifiques, telles que les facteurs économiques, au détriment d'autres, comme les considérations sociales et environnementales. Cette **focalisation déséquilibrée** peut donner une représentation biaisée des progrès et entraver l'évaluation holistique des systèmes énergétiques (Gunnarsdóttir et al., 2020; Shortall & Davidsdottir, 2017). Par exemple, la série EISD proposée par International Atomic Energy Agency (IAEA) et al., 2005) intègre une multidimensionnalité des indicateurs, mais celle-ci est contrastée. En effet, elle compte seize indicateurs économiques, dix indicateurs environnementaux, et seulement quatre indicateurs sociaux. Dans un cas plus spécifique, l'index de sécurité énergétique du Global Energy Institute (2018) comprend des dimensions technico-économique, géopolitique et environnementale, mais n'intègre pas du tout la sphère sociale. Il semble que - à nouveau - ce problème puisse être associé à des problèmes de définition. En effet, même lorsqu'une dimension est prise en compte, sa couverture dépend d'une référence à l'autre. Par exemple, le traitement de la question environnementale peut se restreindre à la consommation d'énergie fossile (Doukas et al., 2012), s'étendre aux problématiques de qualité de l'environnement et de biodiversité (Carraro et al., 2013), ou traiter des déchets issus des systèmes énergétiques (International Atomic

Energy Agency (IAEA) et al., 2005; Portugal-Pereira & Esteban, 2014). Enfin, ce genre de biais peut aussi apparaître dans la définition même des indicateurs. Par exemple, l'indicateur « Share of 'dirty fuel' in residential energy consumption » de Iddrisu & Bhattacharyya (2015) suggère sa propre définition de « dirty fuels ».

1.3.2.3 Problèmes 3 et 4 : pertinence contextuelle et implication des parties prenantes

L'échelle d'application des séries est quasi-systématiquement nationale (Gunnarsdóttir et al., 2020). Il semble presque que ce soit l'échelle d'application par défaut, voire par réflexe. Cela peut éventuellement s'expliquer par le fait que ces séries sont partiellement conçues dans le but de produire des comparaisons internationales. Cependant, elles ne peuvent alors considérer les circonstances et priorités propres à chaque région ou système énergétique. Elles manquent ainsi de **pertinence contextuelle** (Gunnarsdóttir et al., 2020; Shortall & Davidsdottir, 2017).

L'absence de prise en compte des contextes locaux spécifiques peut se traduire par des indicateurs qui ne répondent pas de manière adéquate aux défis et aux opportunités nuancés de chaque contexte. Dans ce sens, Neves & Leal (2010) soulignent la faible quantité de travaux dédiés à la question, mais expliquent qu'une série d'indicateurs locale serait un outil de planification et de suivi essentiel. Pourtant, seules deux séries locales apparaissent dans la revue de littérature de Gunnarsdóttir et al. (2020), parmi 57 séries identifiées. À l'image de série RISE (ESMAP & The World Bank, 2018), l'approche uniformisante des séries existantes les rend inadéquates à leur application à des contextes et échelles variées (Urpelainen, 2018). Dans le cadre des objectifs de développement durable des Nations Unies, cette absence d'initiatives et de données à l'échelle des villes serait d'ailleurs un obstacle à l'atteinte des objectifs qui leur sont dédiés (Klopp & Petretta, 2017). Pourtant, certaines approches permettent de contextualiser les analyses, en impliquant les parties prenantes par exemple.

En plus de permettre une contextualisation de la série s'indicateurs, **l'implication des parties prenantes** a des co-bénéfices multiples. Cela aide à équilibrer la série, améliore sa représentativité, et favorise son appropriation par les parties prenantes (Shortall &

Davidsdottir, 2017; Sovacool, 2012). Pour ce faire, les entretiens semi-directifs ou les questionnaires sont des approches courantes (Jafari et al., 2016; Sovacool et al., 2011).

1.3.2.4 Problème 5 : opacité méthodologique

Enfin, l'**opacité méthodologique**, soit le manque de transparence des méthodologies utilisées pour développer et appliquer les indicateurs de durabilité peut nuire à la crédibilité, et à la fiabilité des indicateurs, ainsi qu'à la réplicabilité des approches. En l'absence de méthodologies claires et bien définies, l'exactitude et la validité des résultats générés par ces indicateurs sont incertaines (Gunnarsdóttir et al., 2020; Shortall & Davidsdottir, 2017). Dans ce sens, Gunnarsdóttir et al. (2020) suggère une grille d'éléments méthodologiques qui doivent être pris en compte. Celle-ci, présentée dans la section 1.3.3.1, a été réutilisée par une méthodologie de construction de séries d'indicateurs qui est présentée en section 1.3.3.3.

1.3.3 Lignes directrices pour la construction et l'usage de séries d'indicateurs

1.3.3.1 Critères pour les séries d'indicateurs

Dans leur revue de littérature dédiée aux séries d'indicateurs en lien avec le développement durable de l'énergie, Gunnarsdóttir et al. (2020) font référence à des lignes directrices préexistantes comme potentiels critères d'évaluation des séries d'indicateurs : les huit principes Bellagio STAMP (Bakkes, 2012; Pintér et al., 2012). Cependant, leur subjectivité ne permet pas de les appliquer directement. Toutefois, l'étude s'en inspire pour extraire ou créer six critères objectivement mesurables, présentés par le Tableau 1.1. En pratique, ils se décomposent en sous-critères dont la validation permet de valider le critère principal.

Tableau 1.1 Critères d'évaluation d'une série d'indicateurs
Adapté de Gunnarsdóttir et al. (2020)

Critère	Raison d'être
1. Transparence de la sélection des indicateurs	Il faut mettre à disposition les choix méthodologiques pour la sélection des indicateurs afin de garantir sa crédibilité et sa légitimité.
2. Transparence de l'application des indicateurs	L'utilité d'une série dépend de la divulgation des informations nécessaires à l'application des indicateurs.
3. Cadre conceptuel	L'application d'un cadre théorique aide à structurer le problème, à accroître l'exhaustivité, à améliorer la sélection des indicateurs, à augmenter sa transparence, et minimiser ses biais.
4. Représentativité	L'ensemble des indicateurs doit prendre en compte les dimensions économiques, sociales et environnementales.
5. Interrelations	Pour améliorer encore une série, il convient d'examiner les liens entre les différents indicateurs afin d'éliminer les indicateurs corrélés.
6. Engagement des parties prenantes	L'engagement des parties prenantes accroît la solidité et la représentativité d'une série. Elle augmente l'acceptation des parties prenantes et réduit le risque de biais.

L'utilisation d'un cadre conceptuel se démarque comme un élément central d'une méthodologie de construction d'une série d'indicateurs. En effet, il participe à la transparence de la sélection des indicateurs, influe sur la représentativité des dimensions, peut faire le lien entre les dimensions et les indicateurs, et peut être construit en intégrant les parties prenantes.

1.3.3.2 Cadres conceptuels

Un ensemble d'indicateurs est construit sur la base d'un cadre conceptuel qui permet une approche méthodologique intégrée et le développement d'une architecture équilibrée et pertinente (OCDE, s. d.). Cela constitue un outil utile à la structuration et la compréhension des problèmes complexes associés aux transitions énergétiques. En premier lieu, un tel cadre définit une **structure organisée** pour aborder un problème complexe. De plus, il peut éventuellement identifier les relations entre différentes variables et domaines, facilitant ainsi la compréhension des interactions et des dynamiques complexes. Deuxièmement, les cadres conceptuels contribuent à la **comparabilité des indicateurs** en établissant des normes et des catégories pour la mesure des différentes dimensions de la durabilité. Cela permet des comparaisons entre pays, régions ou systèmes énergétiques. En fournissant des directives pour la sélection et l'application des indicateurs, les cadres conceptuels garantissent aussi **la transparence et ainsi la reproductibilité** des processus d'évaluation. Ils facilitent également la communication et la compréhension des résultats entre les parties prenantes. De plus, ils aident à **minimiser les biais** en s'assurant que différentes dimensions et perspectives sont prises en compte de manière équilibrée. Cela évite une concentration excessive sur une seule dimension au détriment d'autres aspects. Enfin, ils permettent de **guider les décideurs politiques** en identifiant les domaines d'intervention prioritaires et en mettant en évidence les liens entre les différentes dimensions du développement durable. Cela favorise une prise de décision éclairée et ciblée (Gunnarsdóttir et al., 2020).

Ces cadres émergent dans les années 1970 lorsque le modèle pression-état-réponse (PER) est développé par Anthony Fried et David Rapport (Burkhard & Müller, 2008; OCDE, s. d.). L'OCDE adapte alors ce cadre pour produire des rapports sur l'environnement. Au début des années 1990, l'organisme réévalue la pertinence et l'utilité de ce cadre et affirme sa robustesse et son utilité (OCDE, s. d.). Il est alors utilisé pour développer le premier *Core set of environemental indicators* en 1993 (OCDE, 1993), en réponse au sommet de Rio de 1992 (Khan et al., 2000). Le cadre PER est basé sur des liens de causalité : les activités humaines exercent une pression sur l'environnement, ce qui fait évoluer son état, et la société y répond (OCDE, s. d.). Cependant, il existe d'autres types de cadres conceptuels utilisés dans le développement d'indicateurs. Si le PER intègre la catégorie des cadres de chaîne causale, les cadres thématiques et les approches de dynamique des systèmes constituent deux approches notables. Chacune a ses avantages et ses limites, et il peut être bénéfique de combiner plusieurs approches pour obtenir une vue plus complète et nuancée du développement durable de l'énergie (Gunnarsdóttir et al., 2020). Par exemple, la commission pour le développement durable des Nations Unies (CDD) a utilisé le cadre force motrice-état-réponse (FER), une variation du PER (AIEA et al., 2005; Burkhard & Müller, 2008). Il fait partie des cadres institutionnels qui ont émergé depuis l'Agenda 21, dont un aperçu est présenté dans le Tableau 1.2. Éventuellement, d'autres types de cadre et façons de les classer apparaissent dans la littérature, mais sont moins courantes et plus spécifiques. Par exemple, Waheed et al. (2009) décrivent les cadres « objective-based », « impact-based », « influence-based », « process-based or stakeholder-based », « material flow accounting and life cycle assessment », et « linkages-based ».

Tableau 1.2 Cadres conceptuels institutionnels

Type	Nom	Création	Réf.
Chaîne causale	Pression-état-réponse (PER)	Organisation de coopération et de développement économiques (OCDE)	2, 4
	Force motrice-état-réponse (FER)	Commission du développement durable des Nations Unies	2
	Force motrice-pression-état-impact-réponse (FPEIR)	Eurostat et Agence européenne de l'environnement (AEE)	1, 3, 4, 6
	Force motrice-pression-état-effet d'exposition-action (DPSEEA)	Organisation mondiale de la santé (OMS)	4
Dynamique des systèmes	Cadre pour le développement des statistiques environnementales (CDSE)	Division statistique des Nations Unies (DSNU)	5
Cadres thématiques	Cadre thématique pour les indicateurs de développement durable (TIDD)	Commission du développement durable des Nations Unies	2
1. (EEA, 1999), 2. (Shah, 2008), 3. (Burkhard & Müller, 2008), 4. (Waheed et al., 2009), 5. (Department of Economic and Social Affairs, 2017), 6. (Kenney et al., 2020)			

En dépit de leur pertinence conceptuelle et de leur popularité dans les années 2000, les cadres à chaîne causale ont été progressivement abandonnés en raison de leur complexité et ambiguïté d'application, au profit des cadres thématiques. Ces derniers sont aujourd'hui les plus couramment utilisés. En effet, leur flexibilité et leur capacité à répondre à la plupart des exigences méthodologiques d'une approche de construction de série d'indicateurs les rendent avantageux (Iddrisu & Bhattacharyya, 2015). Ils sont toutefois critiqués pour leur moindre capacité à prendre en compte les interrelations entre les thèmes, là où les cadres de dynamique des systèmes sont plus efficaces, mais bien plus complexes et exigeants sur le plan théorique (Hjorth & Bagheri, 2006).

En résumé, les cadres conceptuels sont des outils essentiels pour guider le processus de sélection et d'application des indicateurs de développement durable de l'énergie. Ils contribuent à une évaluation plus complète, transparente et équilibrée des progrès vers des systèmes énergétiques durables, et facilitent la prise de décision informée pour les parties prenantes et les décideurs. Enfin, les cadres thématiques présentent des perspectives d'application intéressantes, bien qu'un intérêt particulier doive être accordé à leur dynamique, c'est-à-dire aux interrelations entre les thèmes qui les structurent.

1.3.3.3 Description d'une méthodologie intégrée

Prenant en compte la plupart des critiques et recommandations visant les séries d'indicateurs présentées dans les sections 1.3.1, 1.3.3.1, et 1.3.3.2, Gunnarsdóttir et al. (2021) proposent une méthodologie destinée à la construction de séries d'indicateurs multidimensionnelles et ancrées dans un contexte territorial. En particulier, cette approche s'appuie sur les six critères présentés en 1.3.3.2. Il s'agit d'une méthode en sept étapes, impliquant des mécanismes de validation prenant la forme d'itérations (Figure 1.2).

Dans cette méthode, les quatre premières étapes consistent à construire un cadre thématique en se basant sur l'implication des parties prenantes. Pour ce faire, une série d'entretiens semi-directifs ainsi que des groupes de discussion sont réalisés de sorte à en faire émerger les thèmes de la transition énergétique sur le lieu d'étude. Pour valider ces thèmes, ils sont soumis à ces mêmes parties prenantes sous la forme de questionnaires leur permettant de fournir des rétroactions. Le processus est alors réitéré jusqu'à ce que les résultats se stabilisent. Ensuite, le cadre thématique permet de sélectionner des indicateurs, en accord avec certains critères qui considèrent les indicateurs individuellement, et dans le contexte de leur sélection.

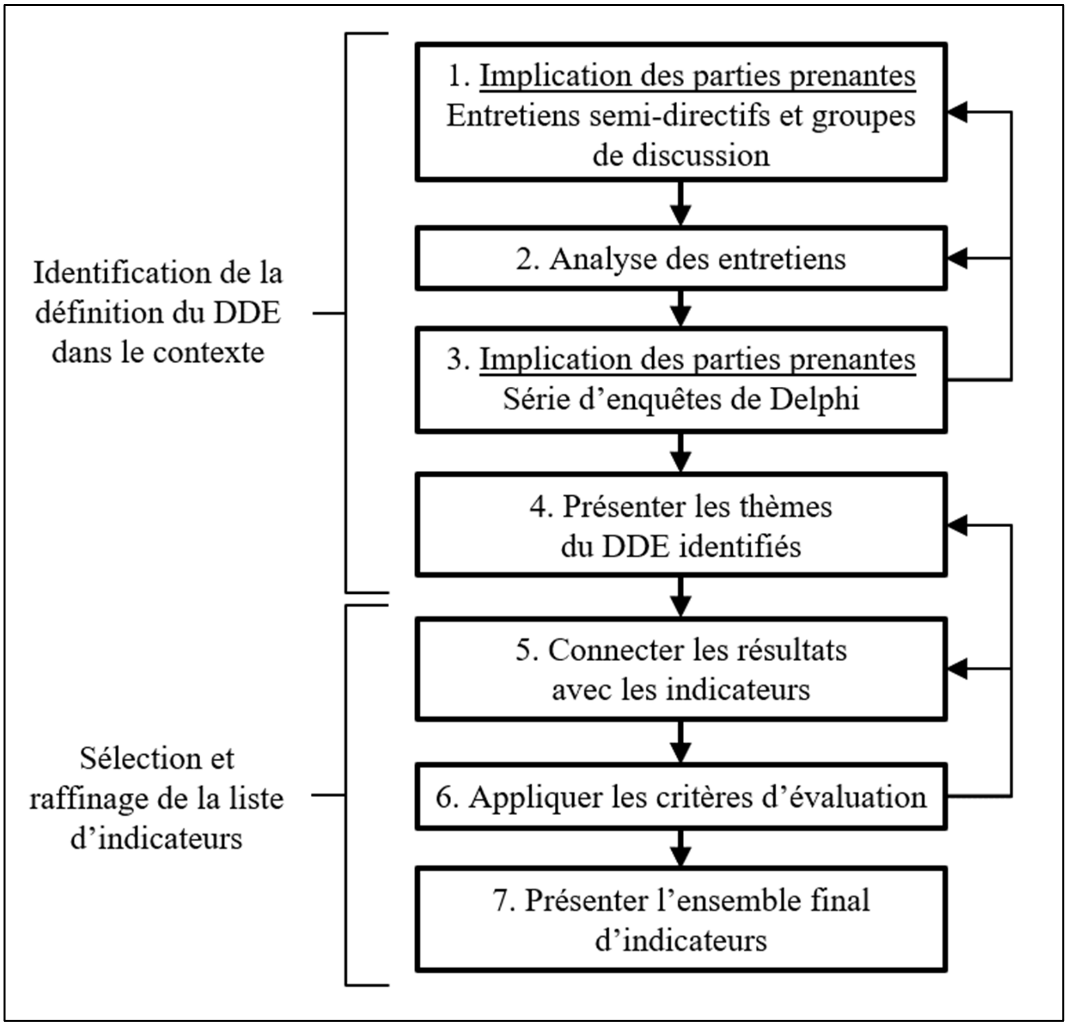

Figure 1.2 Diagramme du processus d'élaboration des indicateurs et de ses sept étapes principales
Adaptée de Gunnarsdóttir et al. (2021)

Toutefois, une des limites de cette méthodologie se trouve probablement dans ces critères. Bien qu'ils soient issus de recommandations émanant de la littérature, ils ne font pas consensus. Cette absence de directives communes est notamment due à la difficile opérationnalisation de ces critères. Ainsi, leur utilité pratique est limitée (Hák et al., 2016). En fait, les évaluer objectivement est difficile car ils sont pour la plupart qualitatifs et complexes (Gunnarsdóttir et al., 2020). Ainsi, aucune approche universelle et complètement objective ne se démarque (Hák et al., 2016). Le Tableau 1.3 donne un aperçu de la diversité des critères évoqués dans la littérature.

Tableau 1.3 Caractéristiques attendues d'un indicateur

Caractéristique	Description / Application à l'indicateur	Réf.
Pertinent et significatif	Il correspond à ce qu'il doit qualifier, a un rapport direct avec l'objectif associé et est adapté aux besoins.	1,2,3
Synthétique et sélectif	Il concentre des enjeux et éléments assez consistants du problème.	2
Clair et facile à interpréter	Il est facile à lire, à comprendre et à interpréter.	2,3,4
Précis	Il définit précisément les grandeurs impliquées.	2
Spécifique	Il est simple à comprendre, clair, précis, compréhensible et non-ambigu.	5
Fiable et sensible dans le temps	Ses valeurs doivent être régulièrement actualisées, comparables dans le temps, et représentatives des variations du phénomène évalué.	1,3,4
Scientifiquement fondé	Il est théoriquement bien fondé.	6,7
Disponible et mesurable	Il peut être quantifié ou qualifié à partir d'une méthodologie. Ses coûts (financiers ou autres) sont compatibles avec les bénéfices qu'il apporte.	1,2,3,4,7
Abordable	Les coûts (financiers, humains, etc.) qu'il engendre sont accessibles.	1
Utile	Il permet d'aider à la prise de décision et à la conduite d'un programme ou d'un projet.	2
Légitime	Les parties prenantes et utilisateurs de l'indicateur l'approuvent.	2,6
Intéressant et responsabilisant	Il permet à son utilisateur et aux parties prenantes de maîtriser les résultats mesurés et d'agir.	2,3
1. (Commission européenne, 2006b), 2. (De Amorim et al., 2005), 3. (Brown, 2009), 4. (Ness et al., 2007), 5. (Commission européenne, 2006a), 6. (Hák et al., 2016), 7. (OCDE, s. d.).		

En résumé, Gunnarsdóttir et al. (2021) suggèrent de construire un cadre thématique en considérant les thèmes émanant des parties prenantes, en intégrant ces dernières au moyen d'entretiens semi-directifs, de groupes de discussion, et de questionnaires. Ce sont là deux méthodes couramment utilisées pour capter des informations qualitatives ou quantitatives de la perception des parties prenantes (Jafari et al., 2016; Walker et al., 2018). Cependant, si cette approche semble complète à la lumière des recommandations issues de la littérature, elle ne peut s'appliquer simplement à tous les terrains d'étude. Notamment, les entretiens s'accompagnent d'enjeux éthiques qui varient selon l'objet d'étude et les populations ciblées (Allmark et al., 2009; Château Terrisse et al., 2016; Gagnon et al., 2019; Hammersley, 2014). Par exemple, le contexte autochtone est associé à des problématiques éthiques particulières, qui existent aussi pour les questionnaires (Donovan & Spark, 1997; Mcgrath et al., 2013). Plus concrètement, il peut aussi être géographiquement ou financièrement difficile d'appliquer de telles méthodes. Cependant, une autre approche permet l'étude du milieu social : l'analyse du discours de presse.

1.4 Analyse du discours

1.4.1 Analyse du discours de presse

Si les discours étudiés peuvent avoir plusieurs origines, une source en particulier est devenue un matériel d'étude répandu : les médias, et en particulier la presse écrite. L'analyse du discours médiatique est un champ d'études utilisé par les chercheurs en sciences humaines et sociales, ainsi que par les observateurs de la vie sociale et politique. En particulier, le discours de presse écrite bénéficie d'une attention singulière (Krieg, 2000). En règle générale, son analyse sert à répondre à la question « qui dit quoi, à qui et comment ». En outre, c'est une méthode scientifique d'appréciation de la perception, de la vision, et des opinions relayées autour d'un sujet évoqué. Elle permet d'évaluer - après coup - l'empreinte persistante d'une thématique abordée par les médias (Chartier, 2003). Dans ce sens, Comby & Lay (2011) s'appuient sur la littérature pour argumenter que la presse locale reflète et influence la société à cette même échelle, malgré la qualité contrastée de l'information qu'elle véhicule. À la manière d'un « miroir imparfait » de la société, elle façonne les attitudes et les perceptions locales envers les événements politiques et sociaux. À travers ses contenus variés tels que les articles et les éditoriaux, elle révèle les cognitions, les valeurs et les comportements liés à différents enjeux, et notamment à ceux en lien avec l'environnement.

Ainsi, Létourneau (2014) utilise par exemple la presse pour évaluer la perception de l'expertise environnementale au Québec et la façon dont elle est communiquée au grand public. Il en ressort que celle-ci est peu représentée bien qu'elle diffuse une information claire et précise lorsqu'elle apparait, laissant ainsi peu de place au scepticisme. Par ailleurs, Comby & Lay (2011) montrent que l'étude de la presse locale est une approche efficace pour appréhender l'évolution spatio-temporelle du système d'acteurs en jeu dans la gestion de l'eau d'une région française. En utilisant une presse s'étalant sur près de trois décennies, elle permet de suivre dans le temps les chemins suivis par un système sociospatial, et particulièrement les virages effectués. Des approches similaires employant des outils d'analyse différents montrent aussi leur efficacité selon plusieurs dimensions et échelles spatio-temporelles, notamment envers les problématiques socioculturelles (Comby, 2013; Comby et al., 2019; Comby & Lay, 2014).

Au-delà de la dimension environnementale, la presse est aussi un matériau d'étude intéressant pour les problématiques associées à la transition énergétique. À ce titre, Desvallées & Arnauld de Sartre (2023) utilisent par exemple l'analyse du discours de presse pour mettre en perspective l'acceptation sociale des technologies de production d'électricité en France. Plus précisément, les auteurs étudient le déploiement éolien offshore et comment il est influencé par l'héritage nucléaire, mettant en évidence l'interconnexion entre les discours à différentes échelles et l'intégration spatiale des systèmes énergétiques. Plus encore, cette étude explore comment ces projets éoliens remettent en question les valeurs établies, les représentations et les paysages énergétiques. Dans ce sens, Meyer (2021) propose une étude comparative de la fermeture de deux centrales nucléaires voisines reposant sur plusieurs indicateurs qualitatifs dont l'un, dédié aux aspects culturels, est évalué grâce à l'étude du discours de presse. Cette approche permet notamment de démontrer l'ancrage territorial des systèmes énergétiques.

Dans le contexte canadien, quelques travaux se penchent sur les discours entourant des problématiques environnementales et autochtones. Chronologiquement, une première étude explore l'interaction entre discours et connaissances dans les audiences publiques pour l'examen environnemental d'un projet de pipeline, mettant en évidence les déséquilibres de pouvoir et les stratégies discursives des peuples autochtones (Luig, 2011). Par ailleurs, une autre recherche met en avant le contraste entre les discours du gouvernement canadien et des communautés autochtones concernant la sécurité environnementale, révélant des disparités et des tensions (Harrington & Lecavalier, 2014). De plus, les médias sont examinés par deux études. La première montre une prédominance des articles traitant de l'opposition autochtone envers les projets hydroélectriques de grande échelle et une omission du contexte historique du colonialisme. Cette recherche remet ainsi en question le rôle des médias dans les relations internations au Canada (Walker et al., 2019). La seconde examine la couverture médiatique des questions environnementales autochtones au Canada et aux États-Unis, mettant en lumière des représentations médiatiques problématiques et l'usage de la force contre les droits autochtones (Lowan-Trudeau, 2021).

Dans le contexte québécois, quelques études offrent aussi un éclairage sur le discours environnemental au Québec. Par exemple, Audet (2015) examine le discours des acteurs de la société civile et du secteur privé entre 2008 et 2014, se focalisant sur la province, mais n'inclut pas la presse au matériau étudié. Le travail de Bertrand (2019), qui se penche sur la construction sociale de l'environnement, est vraisemblablement le seul à utiliser la presse comme support. Toutefois, il se sert de la presse périodique du 19^e^ siècle, difficilement comparable à la presse actuelle. Sur le plan autochtone, le contraste entre le discours environnemental des communautés et du gouvernement québécois est mis en avant par Weigel (2016). Une autre analyse, menée par Desbiens (2004), examine l'impact des relations passées coloniales et politiques dans la création de nouvelles structures de développement pour le renouvellement des ressources dans le nord du Québec. Cette étude met en évidence les discours des Eeyou et des Québécois, en impliquant l'échelle canadienne.

En somme, l'étude de la presse et des discours qu'elle diffuse permet de caractériser la perception des acteurs et parties prenantes des domaines étudiés, d'identifier des problématiques spécifiques au contexte, et de réaliser un suivi temporel et spatial des thèmes et perceptions entourant les systèmes socio-économiques, sociotechniques, ou socioculturels. Toutefois, aucune étude récente de ce type n'a été récemment dédiée à l'environnement, à l'énergie, ou aux populations autochtones dans le contexte québécois.

1.4.2 Applications mixtes et outils d'analyse

L'analyse du discours de presse peut consister en plusieurs approches comprenant des analyses quantitatives et qualitatives. La première catégorie consiste notamment à dénombrer les occurrences d'une « unité d'information », laquelle pouvant être identifiée et analysée grâce à la seconde (Chartier, 2003). Dans le cadre des approches qualitatives, l'analyse critique est la plus courante, et dans une moindre mesure, les approches de théorie ancrée ou « grounded theory » sont parfois utilisées (Comby et al., 2019; Fairhurst & Putnam, 2019; Lowan-Trudeau, 2021; Lowan-Trudeau & Fowler, 2021; T. Meyer, 2021; Weigel, 2016). Cependant, les usages quantitatifs sont courants et sont souvent associés à des méthodes qualitatives. En effet, leur interaction est enrichissante à différents stades de l'analyse (Comby, 2013). En particulier, la revue de presse - c'est-à-dire la construction d'un corpus de presse dédié à l'analyse - constitue en premier lieu une approche qualitative essentielle pour construire un matériau d'analyse approprié. En effet, elle permet de faire émerger des idées structurant une potentielle approche quantitative lors de sa réalisation. Ainsi, l'issue d'une revue de presse et sa pertinence dépendent du couplage « quanti-quali » qu'elle introduit : « en même temps qu'elle décèle le surplus de signification d'un récit de presse, elle le quantifie et l'évalue, dégageant par cette méthode plusieurs renseignements à propos du contenu étudié » (Chartier, 2003).

L'approche quantitative la plus classiquement utilisée consiste à concaténer à la main des informations quant au profil de chaque article d'un corpus préalablement construit autour d'une thématique. Cela permet par exemple de produire une « carte d'identité » de chaque article, sur lesquelles reposent ensuite des analyses susceptibles de mettre en lumière la dynamique globale du corpus (Comby & Lay, 2011; Wagner & Matuszek, 2022). Pour ce faire, il est possible de faire appel à des outils statistiques tels que le logiciel R, ou à des représentations graphiques, et notamment à des cartes, ce qui permet de spatialiser les résultats de l'analyse (Comby & Lay, 2011). Toutefois, des logiciels d'analyse permettant de mener des analyses mixtes, c'est-à-dire parallèlement quantitatives et qualitatives, ont émergé il y a une quinzaine d'années, popularisant ainsi les analyses lexicométriques et textométriques.

Une approche lexicométrique permet d'analyser en profondeur les fréquences et les associations des termes spécifiques utilisés dans le discours, tandis que l'approche textométrique traite plutôt des caractéristiques globales de la structure et de la longueur des textes. Ces analyses, souvent entremêlées, sont permises par des logiciels tels que DtmVic, Hyperbase, N'Vivo, Lexico 5, Le Trameur, TXM, ou encore IRaMuTeQ. Offrant des perspectives d'analyse parfois similaires, ils peuvent aussi se compléter dans le sillage de leurs points forts et points faibles respectifs (Blanchard et al., 2019; Pincemin, 2018). Par exemple, Mayaffre et al. (2019) utilisent TXM et Hyperbase pour l'analyse du discours politique, Comby et al. (2019) utilisent TXM et IRaMuTeQ pour une analyse temporelle multidimensionnelle et Comby & Lay (2014) combinent TXM avec le logiciel R pour une analyse temporelle des représentations du patrimoine naturel. Cependant, IRaMuTeQ se distingue par sa méthode de classification hiérarchique descendante[4] (CHD) reposant sur la méthode Reinert (Reinert, 1983, 1990b, 1990a), ainsi que par ses options de représentation graphique uniques (Pincemin, 2018).

La CHD est une méthode d'analyse de corpus de textes. Avant celle-ci, le logiciel les lemmatise (voir 2.4.3.3) puis les découpe en segments de texte plus courts. La CHD consiste alors à regrouper ces segments en fonction de leur proximité thématique. Pour ce faire, l'ensemble des segments de texte sont divisés en deux groupes aussi « éloignés » que possible (voir 2.4.3.4). Ce processus est ensuite répété sur les deux groupes et leurs descendants jusqu'à ce qu'une condition d'arrêt soit atteinte. En somme, tous les segments de texte constituant le corpus initial sont divisés en plusieurs sous-ensembles : ils reflètent l'existence de plusieurs classes thématiques lexicales. Ces sous-ensembles constituent également de nouveaux corpus pouvant être analysés. Enfin, l'utilité de cette méthode est largement mise en avant dans la littérature (Blanchard et al., 2019; Chaves et al., 2017; El Mujtar et al., 2023; Gamboa et al., 2016; Hamman et al., 2017; Ramos et al., 2019; Souza, 2020; Trigo et al., 2021). Desvallées & Arnauld de Sartre (2023) réalisent par exemple une CHD sur un corpus de 3252 articles de

[4] Aussi désignée par « hierarchichal classification analysis » (HCA) dans la suite du mémoire.

presse dans le cadre d'une analyse des oppositions au développement de l'éolien offshore en France. Les résultats montrent que cinq classes thématiques structurent l'objet d'étude. Une première classe traite de la stratégie énergétique nationale. Une deuxième met en avant les acteurs de l'éolien offshore de l'industrie française. Une troisième évoque les impacts de ce déploiement sur les activités locales. Enfin, une quatrième et une cinquième abordent respectivement la concertation publique et la place des collectivités territoriales.

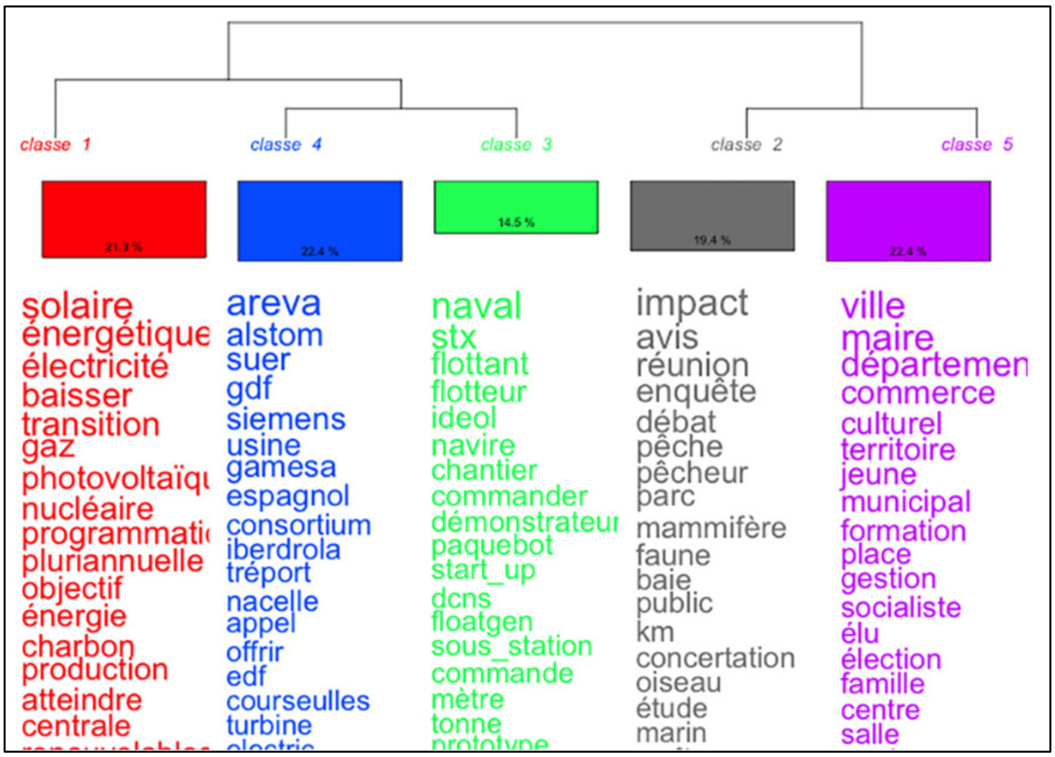

Figure 1.3 Représentation graphique de la CHD
Tirée de Desvallées & Arnauld de Sartre (2023)

CHAPITRE 2

BUILDING A SET OF ENERGY TRANSITION INDICATORS AS IT IS PERCEIVED: A TEXTUAL ANALYSIS APPROACH TO PRESS DISCOURSE

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2.1 Abstract

The energy transition is a multidimensional process that exhibits distinct materialities in space and time. Thus, a situated approach offers tailored perspectives for analysis, particularly when it confronts specific local constraints. Moreover, a multidisciplinary approach enables the capture of increased complexity within the diversity of issues manifesting within a given region. Consequently, this article introduces a methodology based on the examination of stakeholders' perceptions in press discourse to analyse a situated transition qualitatively and quantitatively, constructing an array of multidimensional indicators. The proposed methodology facilitates the construction of a thematic framework attuned to the local context. Furthermore, a new automated approach is introduced to identify interlinkages between thematic classes, along with a new concept of lexical echoes. This methodology holds the advantage of applicability whenever the study area is covered by local or regional press, serving as an alternative to field research when the latter is infeasible.

Keywords: energy transition, indicator, discourse study, framework, IRaMuTeQ

2.2 Literature review

2.2.1 Context

While the energy transition is undoubtedly a technical or technico-economic challenge, it is fundamentally a multidimensional process (Sovacool and Geels, 2016). It transforms socio-technical systems, affects the social environment, and restructures socio-economic actor systems (Miller and al., 2013; Miller and Richter, 2014). Moreover, the regulatory framework for the transition is developed within a political context and encompasses governance issues (Arapostathis and al., 2013; Grubler, 2012; Hainsch and al., 2022; Hoppe and Miedema, 2020; Laes and al., 2014). Conversely, its interactions with the cultural sphere transcend dimensions, and, more significantly, the transition can be examined from a psychological perspective (Omri and al., 2022; Sarrica and al., 2016). Consequently, studies focusing solely on individual dimensions, themes, or sectors in the realm of energy issues encounter limitations (Sovacool, 2013). Conversely, integrated approaches hold greater promise for comprehensively analysing and understanding the dynamics of transition and the barriers that hinder it (Naegler and al., 2021; Omri and al., 2022).

Furthermore, the energy transition is significantly influenced by the specific territorial context in which it unfolds, leading to the consideration of multiple transitions (Sarrica and al., 2016). In this regard, Gunnarsdóttir and al. (2021) position these transitions within a broader framework known as “sustainable energy development”. These transitions can indeed vary from continent to continent, country to country, or even region to region (Lamb and al., 2021; Stringer and Joanis, 2022, 2023). However, the global approach adopted by northern countries tends to standardise the issue and may not fully align with the realities of southern countries (P. Robert, 2021b). Furthermore, the practical implementation of transitions leans towards smaller scales, such as regional, local, or even community levels (Mattes and al., 2015; Mundaca and al., 2018). The diversity of stakeholders and their interests results in technologically specific contexts and territorially grounded governance approaches (Fuchs and Hinderer, 2014). Additionally, energy systems and territories often exhibit high interdependencies (Coenen and al., 2021; Meyer, 2021). Therefore, it is crucial to employ context-driven thinking and analysis to capture the uniqueness of territories and the associated complexities (Cline-Cole and Maconachie, 2016; Huguenin, 2017). This methodology is frequently referred to as a “situated approach” (Cline-Cole and Maconachie, 2016; Robert, 2021).

2.2.2 Measuring the energy transition

Since the 1990s, extensive efforts have been invested in defining and evaluating sustainability. Consequently, a multitude of approaches and tools have been proposed for assessing the sustainability of a region (Doukas and al., 2012; Ness and al., 2007; Singh and al., 2012). This assessment demonstrates its utility in addressing various needs. Specifically, Waas and al. (2014) highlight its relevance in addressing three challenges: the challenge of interpretation, the challenge of structuring information, and the challenge of influence. Thus, it not just plays an "action-guiding" role, but also an "action-generating" one (Waas and al., 2014). Additionally, evaluation contributes significantly to monitoring and shaping transition trajectories, enabling the establishment of goals and the planning of necessary measures for their achievement. Among other advantages, this fosters societal discussions enriched by considerations of potential futures (Grunwald, 2011).

Among sustainability assessment tools, indicator sets and indices derived from an aggregation of indicators stand out as tools capable of capturing multidimensionality (Ness and al., 2007), although the relevance of indices is debated by (Narula and Reddy, 2015). Their rise followed the publication of Agenda 21, whose fortieth and final chapter calls for the development of indicators capable of assessing - at local, regional, national, or international scales - the status and evolution of the various variables characterising ecosystems, resources, pollution, and socio-economic activities (UNCED, 1992). However, Gunnarsdóttir and al. (2020) report that at least five shortcomings commonly characterise existing indicator sets: definitional ambiguity, unbalanced focus, lack of contextual relevance, absence of stakeholder participation, and methodological opacity (Shortall and Davidsdottir, 2017).

2.2.3 New standards and approaches

To tackle this issue, Gunnarsdóttir and al. (2020) propose six straightforward and objectively measurable criteria for assessing indicator sets. Specifically, they draw upon the Bellagio STAMP principles and recommendations found in the literature (Bakkes, 2012; Pintér and al., 2012). These criteria are detailed in Tableau 2.1, and their measurement operationalisation is based on the provided sub-criteria. Subsequently, these criteria have been utilised in the development of a methodology presented by Gunnarsdóttir and al. (2021) and applied in the case of Iceland by Gunnarsdottir and al. (2022). This approach aims to circumvent the deficiencies observed by Shortall and Davidsdottir (2017) in existing indicator sets. It consists of a seven-stage iterative process that involves stakeholders through semi-structured interviews, focus groups and questionnaires. Analysis of these inputs then enables the construction of a thematic framework that guides the selection of indicators. Indicators are chosen iteratively, taking into account five evaluation criteria, and refinement continues until the selection is validated.

While this approach seems highly comprehensive and takes into consideration experiences and recommendations from the literature, it may not be universally applicable to all study areas. Notably, interviews raise ethical concerns that can vary depending on the subject of study and the target populations (Allmark and al., 2009; Château Terrisse and al., 2016; Gagnon and al., 2019; Hammersley, 2014). For instance, the indigenous context presents specific ethical considerations, which are also applicable to surveys (Donovan and Spark, 1997; Mcgrath and al., 2013). In practical terms, geographical or financial constraints can also make it challenging to access the field and implement such research methods. However, an alternative approach for examining the social milieu is through the analysis of press discourse.

Tableau 2.1 Indicator set assessment criteria
Adapted from Gunnarsdóttir and al. (2020)

Criteria	Rationale	Measurability
i. Transparency of indicator selection	It is necessary to make the methodological choices for indicator selection and the underlying indicators of an indicator set available to ensure the credibility and legitimacy of an indicator set.	1/2 - Individual indicators 1/2 - Methodology for indicator selection 0 - Neither of the above and no further analysis
ii. Conceptual framework	The application of a theoretical framework helps structure the problem and can increase comprehensiveness. The transparency of indicator selection can be improved, and bias minimised.	1 - Conceptual framework 0 - No apparent framework
iii. Representative	The indicator set needs to be representative of sustainable energy development, which includes the consideration of economic, social, and environmental dimensions.	1/3 - Economic 1/3 - Social 1/3 - Environmental 0 - None of the above
iv. Linkages	To further enhance an indicator set, the linkages of individual indicators should be considered to show a complete picture and eliminate correlated indicators.	1 - Regression analysis of indicators or causal chain or systems framework or presentation of connected indicators or stated that linkages were considered 0 - Not considered
v. Stakeholder engagement	Stakeholder engagement during indicator selection increases the robustness and representativeness of an indicator set. It increases stakeholder acceptance and reduces the potential for bias in selection.	1 - Stakeholders or external experts engaged 0 - No, not clear if was done
vi. Transparency of indicator application	The usefulness of an indicator set relies on disclosing the necessary information for indicator application and data sources.	1/2 - Methodology for indicator application 1/2 - Data sources 0 - Indicator set not easily calculated again

2.3 Research objectives

In light of the research gaps highlighted by the literature review, this study proposes a new method for constructing a set of indicators. Firstly, the approach aims not to rely, or to rely as little as possible, on a pre-constructed definition of the subject, as suggested by Trigo and al. (2021). The idea is to let the context define what is to be measured. Secondly, this approach must allow multidisciplinarity and multidimensionality to be included, assuming that their distribution is balanced by the context. Thirdly, the approach is context-specific and aims to construct a set capable of contextual monitoring, but not necessarily of producing inter-territorial comparisons. Fourthly, this method attempts to integrate stakeholders by freeing itself from the constraints that accompany the proposal of Gunnarsdóttir and al. (2021). To do this, the press discourse analysis approach is used. Finally, in order to comply with the recommendations in the literature, and in particular to ensure methodological transparency, the six evaluation criteria used by Gunnarsdóttir and al. (2020,2021,2022) are used. More broadly, this paper draws on their work and that of Gunnarsdóttir (2020), and shares common ground with the work of Gamboa and al. (2016).

2.4 Methods

2.4.1 Global overview

The aim of this methodology is to develop a set of indicators capable of measuring the state and evolution of the energy transition in a given area. This is done in five stages, illustrated in Figure 2.1. The need to limit bias in the structure and selection of the set leads to the construction of a selection framework for the indicators. To this end, a thematic framework is constructed on the basis of a sociological approach: the study of press discourse. The study of press discourse is based on the assumption that it allows to appreciate the perception of stakeholders as reflected in the press, and contributes to their indirect participation (see section 2.4.2.1). This leads to the first step (1), which consists of constructing a corpus of texts using a press review, with its geographical scope and objectives to be discussed depending on the context. The second step (2) consists of constructing a thematic framework on the basis of a textometric analysis of this corpus. To do this, the IRaMuTeQ software is used to identify the main themes and sub-themes emerging from the press. This is mainly a qualitative contribution (see section 2.4.3). The corpus is then analysed quantitatively: interactions between themes and subthemes are identified and quantified (3). This makes it possible to select the appropriate indicators, ensuring that they comply with a set of criteria, which is the fourth step (4). The fifth and final stage is the presentation of the set of indicators (5).

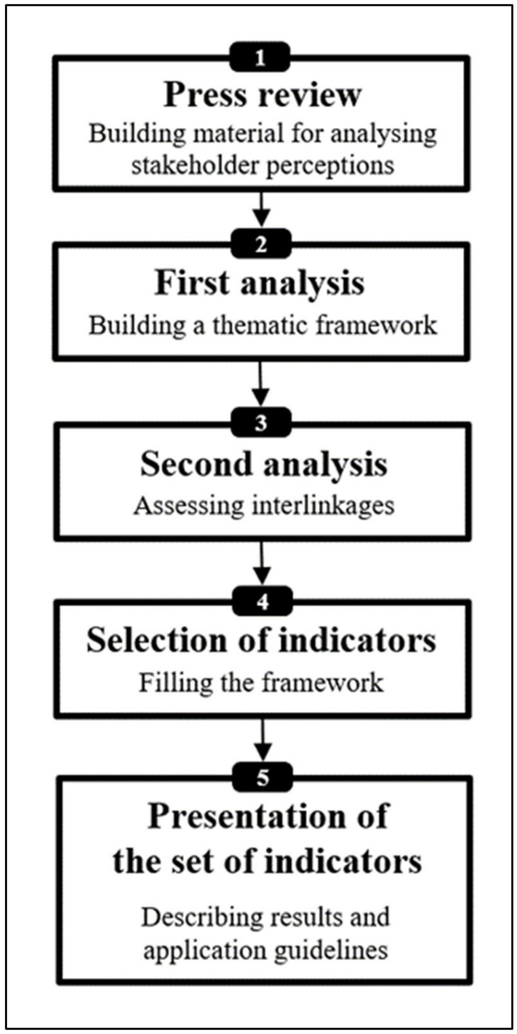

Figure 2.1 Diagram illustrating the main steps of the methodology

2.4.2 Step 1: Conducting a press review

2.4.2.1 Introduction to the analysis of press discourse

Media discourse analysis is a research method employed by scholars in the humanities and social sciences, as well as by observers of social and political phenomena. It primarily focuses on the analysis of written press discourse (Krieg, 2000), aiming to answer the fundamental questions of "who says what, to whom, and how" (Chartier, 2003). This approach serves as a scientific tool for evaluating the perceptions, perspectives, and opinions conveyed on a specific topic, allowing for an assessment of the enduring impact of media coverage on an issue (Chartier, 2003). Furthermore, it proves valuable in capturing stakeholder viewpoints (A. Létourneau, 2014), comprehending the spatiotemporal evolution of stakeholder networks (Comby & Lay, 2011), and delving into socio-cultural matters (Comby, 2013; Comby et al., 2019; Comby & Lay, 2014).

Press discourse analysis can consist of several approaches including qualitative and quantitative analysis (Chartier, 2003). On the one hand, the first category commonly involves critical analysis and, to a lesser extent, the grounded theory approach is sometimes used (Comby et al., 2019; Fairhurst & Putnam, 2019; Lowan-Trudeau, 2021; Lowan-Trudeau & Fowler, 2021; T. Meyer, 2021; Weigel, 2016). On the other hand, although several quantitative approaches exist (see section 2.4.3.1), it appears that these are rarely dissociated from a qualitative approach. Indeed, segregating these two approaches would be inappropriate, as their interaction is enriching at different stages of the analysis (Comby, 2013). For example, a press review - i.e. the construction of a corpus of press dedicated to the analysis - can constitute a mixed approach. While it is primarily a qualitative approach, it provides the material needed for a quantitative analysis and allows ideas to emerge that can structure the latter (Chartier, 2003).

2.4.2.2 Driving theme and objectives of the press review

The press review is framed by the theme of the energy transition in the study area as it is taking place and as it is materialising. More broadly, it is also the perception of energy systems that is studied. As well as helping to construct the thematic framework, understanding perceptions of energy and the services it provides help to interpret the results, and possibly to understand the barriers to the energy transition (Osazuwa-Peters et al., 2020). The aim is to build a corpus encompassing the discourses associated with this transition as perceived by its stakeholders and to deduce the themes around which they revolve. In short, this corpus must constitute study material capable of answering the question: What themes are associated with energy and the energy transition, and how do they interact? Other questions may also guide the study if the specific context of the area under study so warrants.

The approach advocated here postulates that press discourse analysis is likely to overcome the definitional ambiguity of transition commonly present in the literature (Shortall & Davidsdottir, 2017). Indeed, grounding this definition in context through this method provides it with a framework (Trigo et al., 2021). However, the outcome of the press review is sensitive to the parameters used to guide it and these can introduce biases. In order to limit them, they are defined on the basis of contextual elements specific to the area under study (see section 2.4.2.3 and 2.4.2.4).

In addition, the use of press reviews is justified by the fact that it intrinsically brings participation from several dimensions. It "questions" the social, economic and political actors. In short, even if the press review only targets technical or environmental concepts, the results that emerge nonetheless provide multidimensional information. In conclusion, this approach also postulates that the study of discourse enables and should enable conjectures to be made directly with regard to the perception of stakeholders.

2.4.2.3 Framework for developing the initial corpus

To build the corpus, we select articles or pieces of text from the press that are likely to correspond to the themes and objectives of the press review as defined as in 2.4.2.2. Depending on the context, the corpus may be based on newspapers with varying coverage scales: local, regional, national, or other intermediate scales. The scales chosen should be specified and justified on the basis of the characteristics of the case study. Wherever possible, it is advisable to use the press whose scope is comparable to that of the energy system under study. The issues associated with this parameter are twofold. Firstly, too small a scale could exclude certain stakeholders or viewpoints needed to produce a representative analysis. The conclusions drawn would then be simplistic. Secondly, if the scale is too large, there is a risk of inducing too much heterogeneity of stakeholders and viewpoints to obtain readable and relevant results at the scale of the case study.

The current methodology entails an examination of the general public press, where a variety of perspectives are expressed, enabling pertinent analysis as elucidated by Comby & al. (2011). Indeed, while the press exhibits biases, it portrays and disseminates the notions and depictions of societal groups (Grégory & Williams, 1981, cited in Comby et al., 2011). Nonetheless, a comparative study involving specialised press - if accessible - could offer supplementary insights for comprehension.

Finally, the selection period for the corpus also depends on the specific context and objectives of the case study. While it should not be too restricted, a relatively short period - three to five years, for example - has the advantage of facilitating exploration of the problem over a wide perimeter, thus taking into account the diversity of socio-technical interactions (Hamman et al., 2017). However, it should not be too broad, as this could lead to the inclusion of actors and representations that are no longer part of recent reality. Contextual elements are essential for decision-making. For example, if the territory is experiencing a new dynamic with the emergence of new projects and actors that seem to be overhanging the previous dynamic, it may be wise to match the corpus selection to it.

2.4.2.4 Selecting articles and texts: defining keywords

Once the newspapers have been selected, articles or paragraphs corresponding to the themes and objectives defined in section 2.4.2.2 are extracted. Keywords are used to frame and facilitate the search and selection (see 2.4.2.5). However, the choice of keywords can lead to selection bias. For this reason, their use should be justified and used with care. Firstly, they must be chosen according to the framing induced by the discussion on the delimitations of the energy transition (section 2.4.2.2). In addition, it is necessary to be aware of the state of the energy system and the main issues surrounding it. These two elements make it possible to construct a thematic framework to frame the choice of keywords. An example is given in Tableau 2.2, which lists five categories into which keywords can be placed. Finally, the keywords are subjected to an exploratory test on a sample of the press reviews used to build the corpus.

This test helps to identify keywords that appear very rarely, if at all, as well as those that appear frequently. This allows assessment of the effectiveness of the keywords in identifying texts for inclusion in the study corpus. In addition, this step constitutes an initial confrontation with the press, and provides further insight into the transition in the area. In this way, it contributes to suggesting other keywords or deciding to exclude some that might not be relevant. The first role played by this test is to improve the relevance of the keyword list so as to build the most complete corpus possible. On the other hand, excluding less useful keywords can save time in building the corpus. While this approach can be beneficial, modifying the keyword list can introduce biases. Care must be taken to ensure that the list still respects the framing induced by the discussion on the delimitations of the energy transition (section 2.4.2.2).

Tableau 2.2 An example of keyword categories for article selection

<table>
<tr><th>Title</th><th>Description</th></tr>
<tr><td>General concepts</td><td>Depends on global and local transition contexts</td></tr>
<tr><td>Energy sources and carriers</td><td rowspan="4">Depends on the energy system</td></tr>
<tr><td>Energy Production</td></tr>
<tr><td>Energy uses</td></tr>
<tr><td>Actors of the energy system</td></tr>
</table>

Once the list of keywords has been finalised, it's a wise precaution to present more guidelines for their use, starting with their signification (Tableau 2.3). Some words can have several meanings, depending on the context. For example, the word "power", used to refer to cultural or political power, should not be taken into account if the target theme relates to energy. Their meaning must not be open to misinterpretation.

Tableau 2.3 A sample presentation of the chosen keywords

Keywords	Meaning
Energy	In the sense of physical quantity
Sustainable	In the sense of sustainable development
Environment	In the sense of the natural environment: biodiversity, landscapes, ecosystems, water, soil, atmosphere, etc.
Climate Change	In the sense of the phenomenon described by the IPCC

2.4.2.5 Selecting articles and texts: use of keywords

Searching for articles using keywords is based on the mechanism defined by the logical expression (2.1). It describes how a text is found in the first place: if it deals with the area under study and at least one of the defined keywords appears, it is preselected. For certain keywords, it's possible to take into account words from the same root if they belong to the same lexical field. Conversely, certain keywords, particularly proper nouns, are searched for and taken into account only in their exact form. This preselection work can be carried out manually or using search engines dedicated to archiving print media.

Let [keyword_1, keyword_2, … keyword_n] be the list of keywords and territory_name the name of the studied territory. Then, the article search mechanism is defined by the following expression:

territory_name AND (keyword_1* OR keyword_2* OR … OR keyword_n*) (2.1)

where * means that words with the same root are also searched and the use of " " allows searching for the exact word.

Once a text is identified, it is necessary to verify whether it fully or partially corresponds to the analytical framework established in section 2.4.2.2. If that is the case, the entire article or a portion of it is included in the corpus. However, this decision, at times delicate, cannot rely solely on the analyst's judgment. Certainly, the sole presence of one or more keywords at this stage is not a sufficient basis for decision-making. For instance, if the keyword "diesel" appears in an article narrating an anecdote about a lawnmower operating on this fuel, contextual elements may suggest that the connection to the press review's theme is not strong enough for selection. It is crucial to avoid including a text whose theme deviates from the analytical framework, as this could lead to unclear results.

Decision-making mechanisms are therefore used. As a general guideline, if the analyst perceives it is evident that a text's theme aligns with the analysis framework, it becomes a potential candidate for inclusion. In this context, the keyword categories outlined in Tableau 2.2, offer a thematic structure that can provide guidance. Nevertheless, employing a decision support tool is advised to mitigate selection bias. Tableau 2.4 proposes an approach based on three Boolean conditions, their various combinations indicating the appropriate course of action. The purpose of this tool is to exclude text segments that tangentially address information of minimal or no relevance to the subject under investigation.

Tableau 2.4 Decision support: different outcomes depending on the selection conditions

Condition 1	Condition 2	Condition 3	Outcome
The fact told is representative of the way of life or at least of a common usage in the territory studied.	The fact told represents an opinion - even a minority one - on the territory studied.	The story is the result of an accident or a situation that is quite exceptional and small in scale for the territory and the population.	Text is selected
True	True	True	True
True	True	False	True
True	False	False	True
True	False	True	True
False	True	True	False
False	True	False	True
False	False	False	False
False	False	True	False

2.4.3 Step 2: Building the thematic framework

2.4.3.1 Introduction to IRaMuTeQ software

There are several quantitative approaches to analysing the discourse of a press review. On the one hand, the classic approach consists of creating an identity card for each article in the corpus, thus making it possible to analyse the overall dynamics using tools such as R software or graphical representations (Comby & Lay, 2011; Wagner & Matuszek, 2022). On the other hand, lexicometric and textometric analysis, enabled by software such as TXM or IRaMuTeQ, offer complementary perspectives for exploring the frequencies, lexical associations and global characteristics of texts (Blanchard et al., 2019; Pincemin, 2018). However, IRaMuTeQ stands out for its hierarchical classification analysis (HCA), based on the Reinert method (Reinert, 1983, 1990b, 1990a), and for its graphical options (Pincemin, 2018).

HCA is a method for analysing a corpus in order to identify the main themes that emerge from it. In the literature, this approach is widely recognised for its usefulness (Blanchard et al., 2019; Chaves et al., 2017; El Mujtar et al., 2023; Gamboa et al., 2016; Hamman et al., 2017; Ramos et al., 2019; Souza, 2020; Trigo et al., 2021). For example, a study by Desvallées & Arnauld de Sartre (2023) applies a HCA to 3,252 articles in opposition to offshore wind development in France. The results reveal five thematic classes surrounding national energy strategy, wind industry players, local impacts, public consultation and local authorities.

In short, IRaMuTeQ is a text and data table analysis program based on R statistical software and the Python language. Provided with a .txt file as input, it can be used to produce various types of lexicometric and textometric analysis and illustrate them using its interface. All in all, it's a practical tool for the quantitative and qualitative study of text corpuses. However, a number of conditions and settings need to be considered in order to make this study possible. In particular, the text corpus must be written in a single language.

2.4.3.2 Coding the corpus

Each text included in the corpus is introduced by a header. It begins with four asterisks, enabling IRaMuTeQ to detect the beginning of a new text. In order to perform customised analysis, asterisked variables are added to this header (Figure 2.2). These are defined by the analyst and are useful for questioning the corpus. They function as labels assigned to each text. Four variables are proposed for this methodology. The first (variable 1) identifies the newspaper from which the text originates. It therefore includes the name of the newspaper. The second (variable 2) gives the year of publication. The third (variable 3) indicates the geographic coverage of the newspaper: local, regional, provincial or national. Lastly, the fourth (variable 4) indicates the themes addressed by the text. More information on their use is given in section 2.4.3.6.

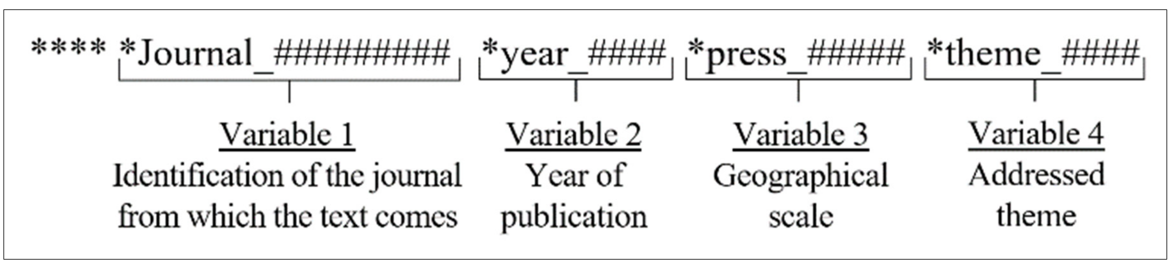

Figure 2.2 Coded header template for each text introduction

For assigning variable 4, it is necessary to standardise and predefine themes across the entire corpus. Specifically, the exploratory keyword test (section 2.4.2.4) and the text selection stage (section 2.4.2.5) provide an overview of the textual content. Subsequently, the analyst can identify and establish recurrent themes within the corpus, assigning one or more themes to each text. To facilitate this process, guidelines must be formulated, encompassing descriptions for each theme and the criteria for labelling a text. Tableau 2.5 illustrates an example of presenting four themes.

Tableau 2.5 Examples of themes used for variable 4

Theme	Variable modality	Description and labelling condition
Economy	*theme_econ	The text deals with economic issues: financing, employment, legislation, and economic development.
Politics	*theme_poli	The text deals with a political figure or political issues.
Energy	*theme_ener	The text deals with energy sources or carriers or means of energy production.
Environment	*theme_envi	The text deals with the natural environment: biodiversity, landscapes, ecosystems, water, soil, atmosphere, etc.

2.4.3.3 IRaMuTeQ operation and analysis settings

Before initiating the analyses, several processing steps are carried out by IRaMuTeQ. First, the software divides the texts included in the corpus into shorter text fragments, referred to as "segments." This operation serves to reduce the heterogeneity of the analysed texts so that they convey only one, or nearly one, sense. These segments retain the assigned variables. In the present case, the segments are divided into sections of 40 words (default setting). Subsequently, these segments undergo lemmatisation using a word dictionary. This involves converting verbs to the infinitive form, singularising nouns, and masculinising singular adjectives. Finally, a sorting process is applied to the "forms," a term used herein to denote lemmatised words. These forms are either eliminated or categorised into two groups: "active forms," also known as "full forms," and "supplementary forms." Default settings are once again employed due to their considered relevance. Consequently, active forms encompass adjectives, adverbs, verbs, common nouns, and unrecognised forms, such as entity or personal names, for instance. Supplementary forms will not be utilised in this study.

Once the corpus has been processed, a range of analyses can be performed. The HCA is used initially to identify the main themes in order to clarify the thematic content within the corpus. Thereafter, the same method is utilised to identify the subthemes.

2.4.3.4 Hierarchical classification analysis (HCA) or Reinert method

HCA consists in grouping text segments according to their thematic proximity. To do this, IRaMuTeQ first divides the set of text segments into two groups as "distant" as possible, using the second-order moment as an indicator, as described in the following paragraph. This process is then repeated on the two groups and their descendants until a stopping condition is reached. Finally, all the text segments making up the initial corpus are divided into several subsets: they reflect the existence of several lexical thematic classes. These subsets also constitute new corpuses that can be analysed.

To quantify the "distance" between two sets of segments, Reinert (1983, 1990a, 1990b) expounds on and defines the computation of the second-order moment, denoted as χ^2 - commonly known as chi2 or khi2. This calculation is performed for every possible pair of segment groups. The closer the χ^2 value is to zero, the closer the proximity between the two groups. Conversely, a higher χ^2 value indicates greater dissimilarity between the groups (Barnier, 2023; Reinert, 1990a). Further elucidations and a concrete example are provided in ANNEXE 2.b.

The subdivision stopping point is determined by two parameters. The first parameter is the desired number of final classes, denoted as N_{class}, which represents the requested count of segment subgroups extracted from the initial corpus. This parameter is adjusted based on the corpus's heterogeneity and size, characterised by the number of text segments (NTS) within the corpus. To fine-tune the N_{class} value, exploratory tests can be conducted. In cases where the content of the final subgroups lacks thematic coherence, increasing the N_{class} value is preferable. Conversely, reducing it is recommended if a single theme appears dispersed across multiple final classes. The final number of classes is designated as N_{f_class}.

Secondly, the minimum size of a class N_{seg} - measured by the number of segments it contains - defaults to the ratio between the total number of segments in the corpus and the desired number of final classes. Finally, two factors are employed to validate the configuration of an analysis: the interpretability of the created classes (see 2.4.3.5) and the proportion of retained text segments (PTS) until the end of the analysis. Indeed, it is possible that certain segments may not fit into the subdivisions and may not be included in the final classes. Maximising the PTS is essential, and it is considered that a PTS exceeding 87.5% provides a comfortable margin and is considered satisfactory (Ratinaud, 2022).

2.4.3.5 Using hierarchical classification analysis

The HCA is used on several occasions to identify the thematic classes represented in the corpus. Each time, its parameters are based on the variables described in Tableau 2.6. The first time, it is applied to the complete corpus. NTS is set by the corpus size, and N_{seg} is set to its default value, i.e. the ratio between NTS and N_{class}. Only N_{class} is adjusted to maximise the value of PTS and the interpretability of the identified thematic classes. However, the latter is subject to interpretation. To do this, the question must be answered: does a single coherent theme emerge from the class? More precisely, two criteria are inspected: homogeneity within a class and heterogeneity between classes. Finally, this assessment is based on the context of the area studied. The tools presented in section 2.4.3.6 are used to operationalise this approach.

Tableau 2.6 Main variables and parameters for HCA analysis

Variable	Type	Description
NTS	Input variable	Number of text segments in the corpus
N_{class}	Analysis parameter	Number of final classes desired
N_{seg}	Analysis parameter	Minimum number of text segments per final class
PTS	Output variable	Share of text segments kept in the final classes
N_{f_class}	Output variable	Number of final classes

This first HCA results in several classes based on sub-corpuses of the initial corpus. A HCA is performed on each of these to identify thematic subclasses (Figure 2.3). As these corpuses are relatively small compared to the initial corpus, there is a risk that some of them will be supported by groups of increasingly less representative text segments. Thus, the parameterisation of these analyses favours a relatively small N_{f_class} value that is easy to interpret, rather than a higher N_{f_class} value whose meaning would be unclear. Also, the classes resulting from the first HCA can be of different sizes and complexities. Their size (NTS) is not a sufficient indicator to predict the variety of themes they contain. A relatively large class is not necessarily the one with the most themes. This time, therefore, the parameterisation is more precise.

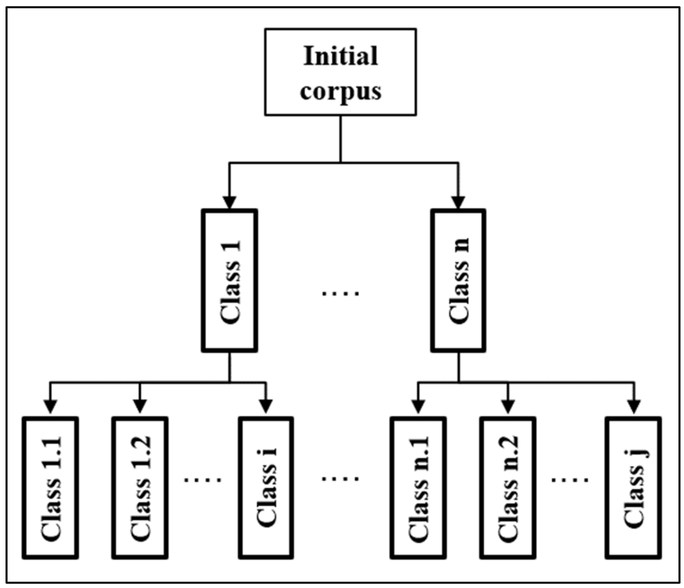

Figure 2.3 Representation of the mechanism for identifying thematic classes and their subclasses

n corresponds to N_{f_class} in the first HCA and i and j correspond to N_{f_class} in the second HCA series for the 1st class and the nth class, respectively.

2.4.3.6 Interpreting the classes

The approach chosen to interpret the classes has two objectives: to assess the relevance of the classification and to give it meaning - if it is validated - by providing a description of each class. To do this, a qualitative analysis is carried out. Firstly, the approach uses the characteristic forms of each class. In fact, each class is based on a list of active forms (see section 2.4.3.3 for a definition) derived from the analysis of the corpus associated with the class. Of these, the most representative are those with the highest χ^2. This involves a statistical calculation similar to that presented in 2.4.3.4, although it differs slightly. This time it expresses the strength of the link between a form and its class. Further elucidations and a concrete example are provided in ANNEXE 2.b[5]. In this way, these forms help to define their thematic class. Secondly, reading the characteristic segments allows linking them to the context. These segments are considered to be the most representative of the class. They are identified automatically by IRaMuTeQ. To do this, each text segment is given a score equal to the sum of the χ^2 of the forms that make it up. The segments with the highest score are the characteristic segments.

For this type of interpretation, the IRaMuTeQ software provides interfaces called "concordancers". These display the forms to be interpreted in the text segments from which they originate, or the characteristic text segments of a class to be interpreted. This approach makes it possible to determine whether a class is too heterogeneous, or not rich enough in meaning, and therefore to adjust the parameters of the HCA. Conversely, it may show that the parameters are satisfactory, enabling the class to be titled and described.

Finally, the analysis of the variables presented in section 2.4.3.2 helps establish the corpus profile by counting the occurrences of some journal, year, scale or theme. In particular, they make it possible to characterise the spatiotemporal contrasts in the corpus, in a similar way to Hamman et al. (2017) or Desvallées et Arnauld de Sartre (2023). Moreover, statistical associations between classes and variables can be assessed using their χ^2 in each class. This should provide discussion points regarding the construction and interpretation of the corpus. Indeed, the representativeness of the corpus can be subject to debate. Consequently, certain parameters of corpus construction can be scrutinised. Additionally, discourse contrasts may be illuminated based on the publication or geographical coverage. This analysis should contribute further material to facilitate commentary on the final results.

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[5] Cette annexe est fournie comme matériel supplémentaire avec l'article soumis.

2.4.4 Step 3: Assessing interlinkages

2.4.4.1 Interlinkages between themes and subthemes

To build connections between classes, an analysis of the n most characteristic forms of each class is carried out, with n to be defined according to the context: number of classes, size of the classes, objectives and accuracy of the analysis, and available resources. This analysis can be carried out directly by IRaMuTeQ for classes derived from the first HCA. Using the software, the n forms of a given class are represented on a diagram according to their χ^2 value in each class. This diagram shows whether one or more of these characteristic forms also exist in other classes, and to what extent. Figure 2.4 illustrates an example. In it, the 21 most characteristic forms of class 4 are plotted according to their χ^2 value for each class. A positive value indicates the strength of the link between this class and this form. Conversely, a negative value indicates how independent the form is of the class. For example, Figure 2.4 shows a relative dependence between the form “développement” and class 1, whereas this form is rather independent of class 7. In the following sections of this methodology, only positive values are analysed, and these are referred to as **echoes**.

This type of diagram - or the analysis it supports - can be used to identify echoes of a class within other classes. These echoes are then considered as points of contact between the classes. However, they can appear in large numbers, and a framework must be established for selecting those considered significant. The choice was therefore made to take an echo into account if, and only if, the value of its χ^2 - noted ${\chi^2}_{echo}$ - exceeds a certain threshold (2.2). This threshold is calculated according to two parameters: ${\chi^2}_{min}$ et τ. The first is given by the lowest value of χ^2 among the n characteristic forms of the class analysed. The second is set according to the context: number of classes, class size, objectives and accuracy of the analysis, and available resources.

$$\chi^2{}_{echo} \geq \tau \cdot \chi^2{}_{min} \tag{2.2}$$

$$\text{With } \tau, \chi^2{}_{echo}, \chi^2{}_{min} \in \mathbb{R}_+$$

These two parameters, and in particular τ, carry a choice made about the significance of the echoes. On the one hand, the value of $\chi^2{}_{min}$ sets a benchmark for the threshold calculated according to the class analysed. It is used to rule out echoes whose magnitude is not comparable to the forms in the origin class. On the other hand, the value of τ is set according to the results of exploratory tests carried out to assess the number of potential echoes and the contrast in their intensities. The approach used is to look for a value of τ for which the values of $\chi^2{}_{echo}$ on either side of the threshold are the most contrasting, so as to retain the most significant echoes. However, a large number of echoes, limited analysis capabilities, or modest analysis objectives may mean setting a lower τ value to simplify the analysis.

Figure 2.4 shows the analysis of one class from a total of eight classes. In this example, exploratory tests show a contrast between the echoes on either side of the threshold for a value of τ set at 0.4. The threshold is then 14.04 for class 4, which explains why the positive echoes in classes 7 and 8 are not taken into account. In this way, only four interrelations with class 4 are identified, including two with class 1 and two others with class 2. This operation is repeated for each class derived from the same HCA, enabling the creation of a thematic network as described in paragraph 2.4.4.2.

This approach can be applied to classes or subclasses derived from a HCA, but its relevance may vary according to their heterogeneity and number. More specifically, if the classes are few in number and relatively general, the results of this analysis may be rudimentary. In fact, they are likely to be superficial and generalist, and therefore unable to provide more information about the complexity of the context studied. Conversely, a high number of classes, derived from a more refined HCA for example, will enable more delicate associations between more precise themes to be identified.

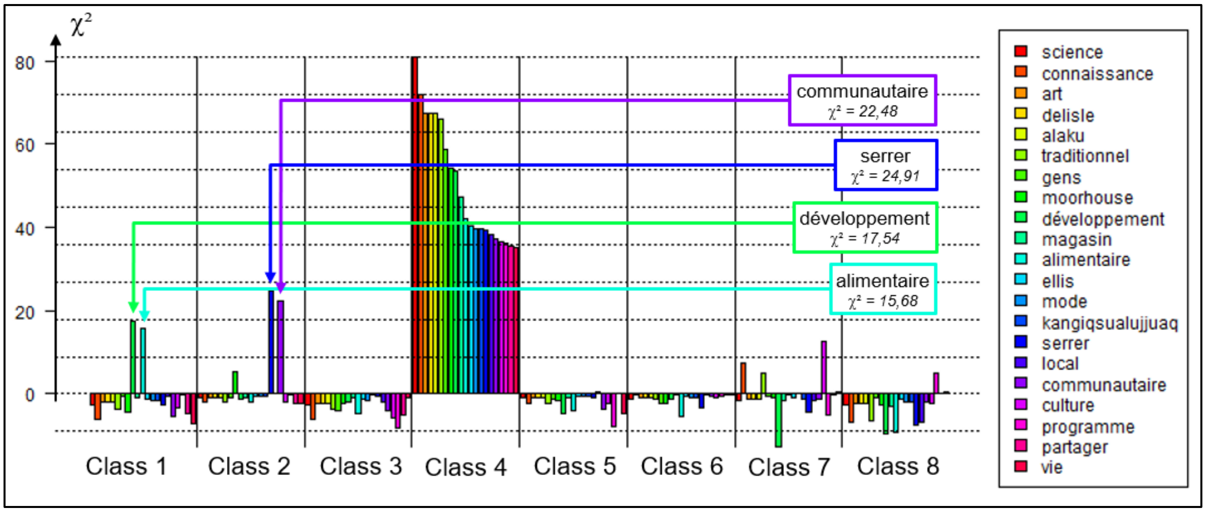


Figure 2.4 Example of χ^2 analysis by class for the most representative forms of a given class

2.4.4.2 Interlinkage coefficients

It is considered that the strength f of an interlinkage between two classes induced by a single echo corresponds to the ratio between the value of $\chi^2{}_{echo}$ of the echo and the value of the χ^2 of the same form in the original class, noted $\chi^2{}_{init}$.

$$f = \frac{\chi^2{}_{echo}}{\chi^2{}_{init}} \tag{2.3}$$

Furthermore, it is considered that the strength F of the total interlinkage induced by one or more echoes between two classes corresponds to the sum of strengths f linkages between these classes. Let n be the number of links between the two classes.

$$F = \sum_{i=1}^{n} f_i \tag{2.4}$$

The analysis of each class can then be supported by quantified interrelations with other classes. To do this, two scopes are used. For a given class, the first scope integrates its links with the other classes which contain one or more echoes of its characteristic forms. For example, Figure 2.5 shows the connections between class 2 and other classes in the case of the first scope. Classes 3 and 7 contain one or more echoes of class 2. These interlinkages are represented by arrows whose width is proportional to the strength F of the link.

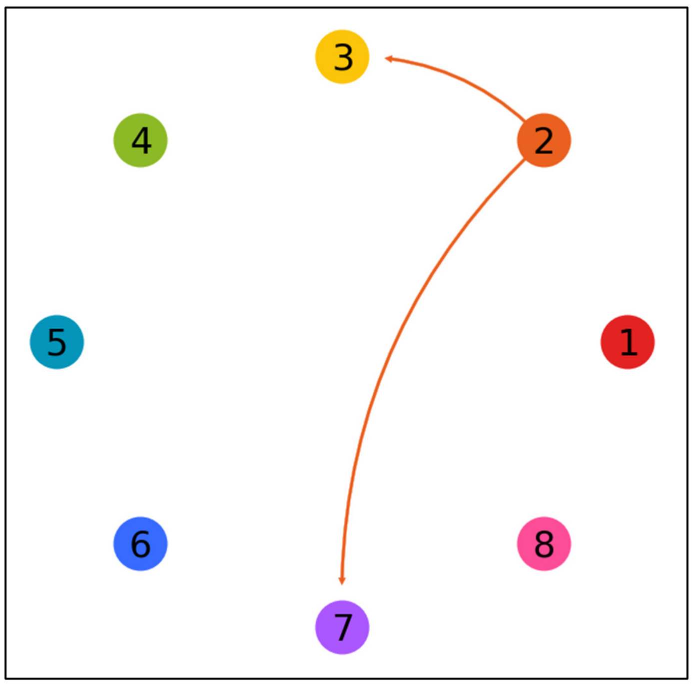
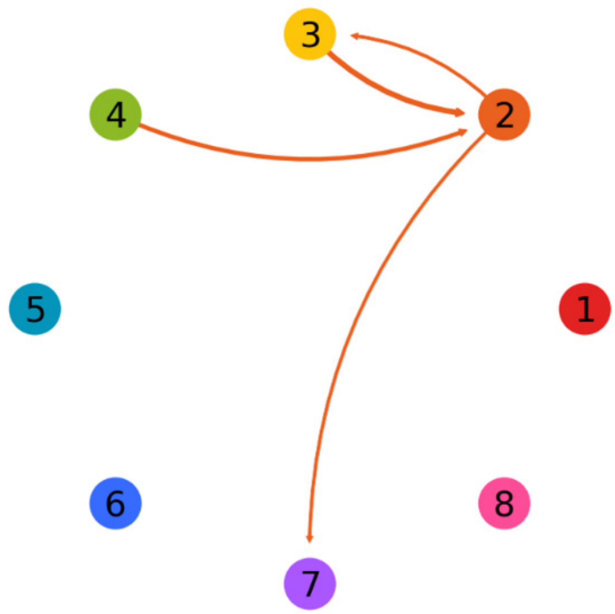


Figure 2.5 Representation of the interrelations
of the first scope for class 2 out of a total of 8 classes

For this same class, the second scope includes connections in the opposite direction. In fact, it takes into account the echoes of external classes in this class. Graphically, this means that it incorporates the interlinkages that start from external classes and end up in the class under study, because the latter contains echoes of the starting classes. For example, Figure 2.6 shows the interrelations in the opposite direction: class 2 contains echoes of the characteristic forms of classes 3 and 4. They are represented by arrows going from one of these two classes to class 2.



Link	F
3 to 2	2.08
4 to 2	1.24
2 to 3	0.62
2 to 7	0.55

Figure 2.6 Representation of the interlinkages of the second scope
for class 2 out of a total of 8 classes

2.4.4.3 Practical application of the method

In practice, this method requires a few guidelines. Firstly, each of the interlinkages must be interpreted in the light of the echoes that make it up. In fact, some of them may be based on forms that have an innocuous meaning, or on forms that are identical but have different meanings depending on the context. In this case, the connections should not be taken into account. More specifically, this interpretation must aim to identify the common point or meeting point between the two classes that is highlighted by the echo. To do this, an analysis of the concordancers of the echo in the source and destination classes is carried out.

Secondly, while the detection of echoes as defined in 2.4.4.1 can be done using IRaMuTeQ in the wake of the first HCA, this is not the case for the second HCA. So, after extracting the list of active forms in each class, including the characteristics of each and in particular the values of χ^2, the analysis was automated using several algorithms in the Python language. They are included in the supplementary files to this article (see ANNEXE 2.a). They provide several ways of displaying the results. In particular, they allow the first (Figure 2.5) and second scope (Figure 2.6) interlinkages for each class to be displayed.

Thirdly, the use of this approach is useful for constructing the set of indicators and interpreting it. In fact, identifying interlinkages allows the interpretation of a class in the light of the context and the other themes. Indeed, the sectorisation of the case study certainly makes it possible to take into account the diversity and multidimensionality of the transition issues, but it still constitutes a simplification of reality. In other words, sectorisation is a useful but fictitious division. Thus, these interlinkages make it possible to make the modelling more realistic in relation to the real interweaving of issues.

2.4.5 Step 4: Indicator selection

2.4.5.1 Initial bank of indicators

Once the thematic framework is established, the selection of indicators is initiated using the review of indicator sets published by Gunnarsdóttir et al. (2020). This work analyses existing indicator sets according to the six criteria presented in Tableau 2.1. The result is that of the 57 sets identified, only the Energy Indicators for Sustainable Development (EISD) set meets all of them (IAEA et al., 2005). It is therefore an interesting basic set, although it is too general to be applied as such to specific contexts (Gunnarsdóttir et al., 2020). In addition to analysing indicator sets, this study indirectly provides access to a bank of indicators that can be used. All sets meeting the "Transparency of indicator selection" criterion and the "Methodology for indicator application" component of the "Transparency of indicator application" criterion are selected to build an indicator bank. The first requires the sets to present each of its indicators individually, as well as the reason why each has been selected. The second requires the methodology for applying the indicators to be provided.

In all, 17 sets of indicators meet both criteria and are presented in Tableau 2.7 alongside the set produced by Gunnarsdottir et al. (2022), which also meets both criteria. They do not all cover the same themes, and some are even specific to a single dimension. In particular, the renewable or sustainable nature of energy, the security of the energy supply, as well as efficiency, reliability and productivity are among the themes most dealt with in these sets. A proportion of the indicators also deal with the social aspects of energy and the environment. Finally, other contextual elements are introduced by economic and institutional indicators. Furthermore, most of the indicators used are quantitative, but some are qualitative. In particular, the RISE set presents exclusively qualitative indicators designed to construct indices. Finally, it should be noted that the precision of the methodology used to apply the indicators varies from one reference to another.

To facilitate the use of these indicators, they were extracted and arranged by category and subcategory using an empirical approach (see ANNEXE 2.c). More specifically, each indicator was associated with the main dimensions of which it was composed. In addition, the categories were adjusted to be relatively balanced, and subcategories were created to make them easier to read. These were inspired by the classifications proposed in the different sets. Some indicators from different sets have been grouped together when their meaning was identical or very similar, and in particular when the units characterising them were coherent. In some cases, one indicator may encompass another. For example, this is the case on several occasions with the indicators in the EISD set, which have relatively broad definitions. However, this type of grouping was not done as soon as it risked eliminating the specificity of an indicator. Finally, the indicators from the RISE set have not been included. Their structure does not make this arrangement as relevant as for the other indicators. Firstly, each is an index built on a series of qualitative indicators, and the latter are all indicators in their own right. Their multidimensional nature, although based on regulatory aspects, makes them difficult to classify. Furthermore, as the indicators in sets 6, 7 and 8 are taken directly from the EISD set, they have not been processed.

Tableau 2.7 Sets of indicators meeting the transparency criteria
Based on Gunnarsdóttir et al. (2020)

N°	Name of the set	References
1	Sustainable Energy Development Index (SEDI)	(Iddrisu & Bhattacharyya, 2015)
2	Regulatory Indicators for Sustainable Energy (RISE)	(Banerjee et al., 2017; ESMAP & The World Bank, 2018; World Bank Group, 2014)
3	Energy sustainability index	(Doukas et al., 2012)
4	Energy sustainability index (ESI)	(Mainali et al., 2014)
5	Energy indicators for sustainable development (EISD)	(IAEA et al., 2005; Vera et al., 2005; Vera et Abdalla, 2006; Vera et Langlois, 2007)
6	Sustainable energy development indicators for EU energy policy 1	(Streimikiene & Šivickas, 2008)
7	Sustainable energy development indicators for EU energy policy 2	(Štreimikienė, 2015)
8	Sustainable energy development indicators for EU energy policy 3	(Siksnelyte et al., 2019)
9	Aggregated energy security performance indicator (AESPI)	(Martchamadol & Kumar, 2013)
10	The U.S. Energy Security Risk (Index)	(Global Energy Institute, U.S. Chamber of commerce, 2018)
11	Risky External Energy Supply (REES) index	(Le Coq & Paltseva, 2009)
12	Electricity generation security of supply indicators	(Portugal-Pereira & Esteban, 2014)
13	Energy security index 1	(Sovacool et al., 2011)
14	Energy security index 2	(Sovacool, 2013)
15	Renewable Energy Sustainability Index	(Cîrstea et al., 2018)
16	Renewable Energy Responsible Investment Index (RERII)	(Lee & Zhong, 2015)
17	Multidimensional Energy Poverty Index (MEPI)	(Nussbaumer et al., 2012)
18	Indicators for sustainable energy development for Iceland	(Gunnarsdottir et al., 2022)

Finally, the selection of indicators should aim at establishing connections between the thematic subclasses, their content, and the constructed indicator bank. However, it is possible that the results from Step 2, and to a lesser extent from Step 3, cannot be represented by this initial bank of indicators. The specificity of the context, taken into account by the thematic framework, could be at the origin of this. Two approaches are therefore conceivable. On the one hand, a search for complementary indicators can be carried out in the literature. This can be done by using keywords to describe the issues emerging from the thematic framework. On the other hand, indicators can be proposed and defined by the analyst if the content of a class clearly suggests so.

2.4.5.2 Validation of indicator selection

A large number of recommendations exist regarding the criteria that indicators should meet (Adelle & Pallemaerts, 2009; Brown, 2009; De Amorim et al., 2005; Ness et al., 2007). However, many of them are difficult to interpret objectively, as are several of the Bellagio STAMP principles. Their practical usefulness is therefore limited (Gunnarsdóttir et al., 2020; Hák et al., 2016). The method proposed by Gunnarsdóttir et al. (2021) based on the five evaluation criteria in Tableau 2.8 is no exception to this problem. They are qualitative and their evaluation is based on subjective judgement.

In the absence of a more objective approach, these criteria are used to refine and validate the choice of indicators. Like Gunnarsdóttir et al. (2021), they are used as part of an iterative method: as long as the indicators do not meet these criteria, their selection is refined. Finally, Gunnarsdóttir et al. (2021) justify that their approach makes it possible to satisfy other common criteria through the way in which the thematic framework is constructed. These criteria are representativeness, policy relevance, stakeholder acceptability and interest, and the use of a transparent methodology and conceptual framework. This assumption can also be applied to the present method, which is based on foundations comparable to those of Gunnarsdóttir et al. (2021).

Tableau 2.8 Indicator assessment criteria based on commonly used criteria for indicator selection
Taken from Gunnarsdóttir et al. (2021)

Criteria	Brief description
Interpretability	Simple, easily interpreted, and applied.
Trends	Sensitive to changes and shows trends over time.
Grounded in research	Theoretically sound and measured based on standardised measurement methods that enable international comparison of indicators.
Data availability and quality	Based on data of good quality that are available or readily collected. Data are collected regularly and reported with a minimal time lag to report current information.
Linkages	The interrelation of indicators should be considered to eliminate correlated ones. Indicators should be meaningful on their own as well as together with other indicators of the set.

However, the "Data availability and quality" criterion is used with caution. Indeed, the role of this methodology is also to highlight the absence of data for certain key statistics. Furthermore, since indicators can be socio-political tools, the existence of the data needed to calculate them may reflect the producer's desire to align with or oppose a political construction of energy or the environment (Bouleau & Deuffic, 2016).

2.4.6 Step 5: Presentation of the indicator set

By applying the four previous steps, a dynamic set of indicators can be constructed, organised by thematic classes or subclasses. The next step involves effectively utilising these indicators, following a set of guidelines, including those proposed by Gunnarsdóttir et al. (2021). In particular, visual communication of the results, accompanied by summary descriptions, would make it possible to reach a wider range of stakeholders. This methodology also provides specific descriptive tools such as interlinkages and the analysis based on the variables introduced in section 2.4.3.2. The former tools make it easier to interpret the complexity of the issues involved in energy transition, while the latter tools help attribute a theme to a type of stakeholder, a geographical scale, or a time period. Giving indications as to a theme particularly linked to one of these variables can benefit the transparency of the thematic framework, as well as the understanding of the context. In addition, regular updating - on an annual basis, for example - of the evaluation of the indicators would make it easier to monitor changes in energy systems. The global approach also needs to be replicated in order to update the conceptual framework. In fact, the structuring themes are also bound to change as a result of certain significant transformations in the energy landscape of the study area. To do this, it suffices to update the corpus of the press studied. Among other things, updating the set - whether or not new themes and indicators emerge - would make it possible to paint a chronological portrait of the energy transition and its perception by stakeholders.

2.5 Discussion

2.5.1 Qualities and novelty of the methodology

Based on a textual analysis, this methodology makes it possible to construct an indicator set that validate the six evaluation criteria introduced by Gunnarsdóttir et al. (2020). In particular, it enables the construction of a multi-dimensional thematic framework that presents internal interlinkages and takes into account the perception of stakeholders. Furthermore, the construction of the thematic framework is not based on a restricted or pre-constructed definition of the energy transition, thus overcoming any definitional ambiguity. On the contrary, it emerges from the press in a shape that depends on the territory and represents the dimensions in which it operates at that scale. The multidimensionality of transition is therefore not restricted to any previously imagined framework. Only the keywords used to construct the press corpus provide a framework for the analysis. In addition, IRaMuTeQ's use of qualitative and quantitative tools enables “bridging” between disciplines, as suggested by Geels et al. (2016). In particular, an innovative method, introducing a concept of lexical echo, makes it possible to identify thematic interlinkages and to highlight the systemic and interdisciplinary complexity associated with transition. This approach thus provides additional keys to understanding the indicator set and the energy context of the study area.

Secondly, the only necessary condition for its application is the existence of a local and possibly regional or national press. It can be used as part of a situated approach, and the scale of the study can be adjusted when the corpus is constructed. In addition, the textual approach allows the perception of stakeholders to be analysed even when the field of study is inaccessible, or a lack of resources prevents it. This is one way of facilitating the study of less developed countries or regions, which tend to be less studied (Sovacool, 2013). This also assumes that it is relatively easy to replicate the method, whether to discuss the proper design of the corpus or even the thematic framework, or to update the indicator set. New themes may emerge as a transition evolves. Consequently, the ease with which the method can be replicated is an asset for better monitoring.

Moreover, the variables introduced in 2.4.3.2 allow questioning the corpus and to justify the need to reconstruct it if it has any flaws. In this way, the list of keywords used to construct the corpus can be enriched or adapted if this improves the representativeness of the results. For example, some keywords correspond to the names of transition stakeholders, identified by prior work on the energy context of the region. However, this list can be expanded if a stakeholder is overlooked. In particular, it can be submitted to experts in the socio-technical system under study to complete it.

2.5.2 Limitations of the press discourse approach

Although this method postulates that the press can play the role of a proxy for stakeholders, it is debatable whether textual analysis of the press can really replace approaches such as semi-structured interviews. On the one hand, the characteristics of the corpus analysed influence the representativeness of the results. In short, good practice allows to control the quality of the corpus but introduces more uncertainties than the stakeholder map proposed by Gunnarsdóttir et al. (2021) and applied by Gunnarsdottir et al. (2022). In particular, there is a risk that certain stakeholders or categories of stakeholders will be absent or will occupy a disproportionate place. On the other hand, the press analysis does not integrate the same perspectives of appropriation of the indicator set by the stakeholders. Indeed, it does not follow principles of participation or co-construction (Montedonico et al., 2018). In addition, this approach may also incorporate ethical issues, particularly in indigenous environments, where the history of the territory studied includes colonial issues (Aveling, 2013). Despite everything, the proposed method has the advantages of a situated approach and does not adopt the homogenising approach induced by the dominant definitions of energy transition (Cline-Cole & Maconachie, 2016; P. Robert, 2021b).

Furthermore, the press is only a partial source of information, focusing on the supposed interests of its audience. It does not match the rigour and complexity of scientific sources, particularly when it comes to ranking environmental issues (Comby, 2013). As a result, the thematic framework constructed may be scientifically biased. A theme could appear with a different scope or approach from what is apparent from the transition objectives suggested by the scientific literature. In particular, the dissemination of information associated with transition varies and may carry the interests of certain economic or political actors politiques (Černý & Ocelík, 2020; Lyytimäki et al., 2018). While such a difference would be an interesting analytical result, it would pose a problem regarding the reliability of the indicator set.

To overcome this issue, a partial framing based on scientific literature or expert opinions could be introduced (Hák et al., 2016). This could also be done with IRaMuTeQ, by integrating expert discourse into the corpus (Sousa et al., 2020). Eventually, bridging the results with structuring documentation of sustainable development objectives, such as the report by Adelle et Pallemaerts (2009), would also help to limit this bias.

2.5.3 Limitations of the method and future research

A few aspects of the methodology have been identified as sources of uncertainty. Firstly, the development of the press corpus is sensitive to the parameters applied to it and to the content provided: keywords used, period of selection of articles, and diversity of journals used. The corpus is also influenced by the selection choices made by the analyst, although a decision support tool is used.

In addition, the analysis parameters applied to IRaMuTeQ influence the results. In particular, the HCAs are adjusted using a qualitative and quantitative approach that is subject to the analyst's interpretation (see sections 2.4.3.5 and 0). Thus, a different understanding of the case study may lead to different choices to be made from one analyst to another, particularly with regard to the assessment of class heterogeneity. Similarly, the echo selection threshold is subject to interpretation or arbitrary choice (see sections 2.4.4.2 and 2.4.4.3).

Finally, the way in which the indicators are chosen remains relatively simplistic and uncritical, despite the application of evaluation criteria. In fact, these criteria, although derived from recommendations in the available literature, are relatively subjective and therefore difficult to operationalise. In addition, traditional energy indicators and their use have been called into question by Kraan et al. (2019). Their work suggests that certain physical quantities traditionally used to describe energy systems are losing their relevance and representativeness as the energy transition and decarbonisation of systems proceeds. In the light of their recommendations and the views emerging from the literature, consideration could be given to the choice of indicators.

In conclusion, at different steps in the application of the methodology, its reliability would be enhanced by comparing the views of several analysts, especially if they come from different disciplines. This would be likely to limit interpretation bias, or at least highlight it. Indeed, the selection of articles for the corpus, the analysis and search for the best HCA parameterisation, and the choice of the value of τ could be part of a validation process. It could take the following structure: each of these methodological stages would be carried out by several analysts without them being able to consult each other beforehand or during their work. A posteriori, similar interpretations and results would make it possible to affirm that the present methodology entails little bias. Conversely, significant discrepancies would highlight areas for improvement.

2.5.4 Application prospects

Although sets of indicators produced using a situated approach cannot be used to compare regions with different indicators, the existence of disparities in their structuring themes can (van Zeijl-Rozema et al., 2011). This is especially true if they are updated over time, since they would then make it possible to characterise and compare the appearance and disappearance of certain themes, reflecting changes in transitions.

This methodology, as a situated approach, is particularly well suited to isolated regions. For example, it could be applied to North American indigenous communities. In particular, conducting sociological studies in these communities encounters various constraints (Aveling, 2013; Donovan & Spark, 1997). Specifically, Canada's northern regions are potential candidates for application (Assemblée des Premières Nations du Québec et du Labrador (APNQL), 2014). It could also help to identify statistical gaps and thus contribute to the implementation of relevant data collection (Farsari & Prastacos, 2002).

Finally, despite its local and context-specific nature, the methodology can be applied to a variety of scales. To go to a smaller scale, the lower limit is induced by the possibility of building a usable corpus. On the other hand, the upper limit depends on the objectives of the study, and in particular the desired level of detail of the results. A corpus covering increasingly large scales is likely to be increasingly heterogeneous. Depending on the parameters of the HCA, a significant part of the complexity of the socio-technical systems studied could be unreadable. For this reason, the scale of the study should only be extended if there is a certain degree of coherence between the territories and transitions studied. For example, the similarity of the energy, technical, social and ethnic issues involved in the energy transition in northern Canada would make this region a good candidate (Cherniak, 2015).

2.6 Conclusion

The multidimensionality of transitions and their interweaving with space and time lead to the proposal of analysis methodologies that draw on several dimensions and to the adoption of a situated approach. This article suggests using the qualitative and quantitative aspects of the study of discourse to construct a set of indicators that responds to these issues, based on the methodological proposal of Gunnarsdóttir et al. (2021). Unlike their study, which uses semi-structured interviews, focus groups and surveys to construct a thematic framework, our method is based on press discourse. This is analysed using IRaMuTeQ software, and in particular Hierarchical Classification Analysis (HCA), which is used to extract the main themes and sub-themes associated with the energy transition. This thematic framework makes it possible to limit bias in the selection of indicators. In addition, a new approach introduces a new concept of lexical echo, making it possible to identify complex thematic interlinkages that are characteristic of the system under study.

The advantage of this method is that it is not based on a pre-constructed definition of transition and is therefore anchored in the context. However, the biases introduced by the press may limit the representativeness of the thematic framework, its proximity to a science-based structure, or its function of balancing dimensions and themes. Among other sources of uncertainty, the approach proposed in this article nevertheless shows promising potential for producing analyses of territories that are difficult to access for field studies. In particular, regions inhabited by indigenous populations, notably in North America, offer potential for applications.

CHAPITRE 3

NUNAVIK ENERGY OUTLOOK: A REVIEW

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3.1 Abstract

Nunavik constitutes the northernmost region of Quebec, encompassing the entire territory beyond the 55th parallel. It is characterized by geographical isolation and distinctive energy patterns, heavily reliant on petroleum products for both electricity generation and heating. Consequently, driving an energy transition within this region becomes imperative. However, attaining a comprehensive perspective on its energy landscape is challenging due to the absence of organized statistical data, thereby requiring a cautious analytical approach. This article therefore aims to reduce this gap by reconstructing its recent energy history and concatenating the available data. To this end, an in-depth literature review is carried out. The results show a recent development of renewable energies in electricity production, and a diversified but contrasted, uncertain or little-exploited potential in other sectors, notably for heat production. On the other hand, it appears that the statistical coverage available is relatively poor, particularly for non-electrical energy uses. Finally, some of the constraints weighing on energy production and consumption are presented and discussed. In conclusion, recommendations are made to improve statistical coverage of the region.

Keywords: Nunavik, northern communities, autonomous grids, energy transition, indigenous

3.2 Introduction

Nunavik is an isolated region of Quebec where the energy context differs radically from the rest of the province. Indeed, Quebec's hydroelectric generation capabilities give it a recognized energy advantage in North America, both in terms of supply and greenhouse gas emissions. However, the northern third of the province - the territory of Nunavik - is cut off from the rest of the province at the 55th parallel, above which Quebec's integrated power grid does not extend. As a result, Nunavik is particularly dependent on fossil fuels, especially for power generation and residential needs. It is therefore the focus of special attention as part of the region's energy transition, which also takes place in a particular socio-economic and cultural context. Nunavik is mainly inhabited by Inuit and Cree populations, and has a specific system of governance.

That said, an observation made by Duhaime (2007) and Glomsrød and al. (2021) in the socio-economic sphere is also true in the energy sector: Nunavik does not benefit from statistical coverage comparable to that of a province, and it is sometimes difficult to evaluate or access certain indicators. The aim of this work is to provide a simple, up-to-date picture of energy in Nunavik, to facilitate analysis of the region's energy system. More specifically, it aims to update or complement other works, such as the inventory of northern regions published by Cherniak and al. (2015), the Nunavik-specific synthesis published by Karanasios and Parker (2017), and the dissertations by Boisseau-Bouvier (2019) and Harbour-Marsan (2018) which contain entire sections dedicated to the inventory. The latter, moreover, presents contextual elements that will not be discussed again in this work, which is intended to be more technical, although Belzile, Comeau, and al., (2017) propose further research on this front. Finally, this work could be a humble contribution to the construction of a basic foundation for more data collection and sharing in Nunavik, along the lines of the reports by Whitmore and Pineau (2023).

This literature review was based on a systematic reading of Hydro-Québec Distribution's (HQD) supply plans and their supplements, as well as Hydro-Québec's (HQ) strategic plans. These documents played a structural role as well as being a valuable source of information. Public documentation from the Kativik environmental quality commission (KEQC) was also useful[6]. The rest of the information was found in existing literature, in the press, or in documentation provided by certain companies or institutions. First, this document provides background information on the geographic, energy and socio-economic situation of Quebec and Nunavik. Next, a historical portrait of energy production - particularly electrical energy - is presented, covering the past decades and years up to the present day. In addition, technological prospects for energy production are introduced on the basis of recent scientific literature. Next, a profile of production capacities and energy consumption is presented. Once again, the focus is on electricity, but other sectors and consumption items are also covered. Finally, a section is devoted to the question of electricity production and sales costs, as well as measures to control consumption.

3.3 Context of an isolated region

3.3.1 Canadian geography from national to regional scale

Canada is the second-largest country in terms of surface area (9,984,670 km²), but is much less populated than other countries with a similar size (INSEE, 2016; UN and Department of Economic and Social Affairs, 2019). Its low population density reflects - among other factors - the uneven distribution of its inhabitants across the country. There is a marked contrast between the south and the north of the country, the former being much more densely populated than the latter, particularly north of the 55th parallel. For example, Yukon, Nunavut, the Northwest Territories and Nunavik account for nearly 44% of Canada's land area, but only 0.36% of Canada's population in 2016 (Duhaime and al., 2021; Canada, 2017; Ministère des Affaires municipales et de l’Habitation (MAMH), 2022; Statistics Canada, 2017). This north-south disparity is also apparent in Quebec, at the level of administrative regions, for example.

[6] Cette institution est principalement désignée par l’acronyme francophone CQEK dans ce document.

Of the province's 17 administrative regions, Nord-du-Québec is both the most northerly and the least populated, in terms of both number of inhabitants and population density (Tableau 3.1).

Tableau 3.1 Population, surface area and population density in several regions of Quebec
Drawn from Institut de la statistique du Québec (2021) and MAMH (2022b, 2022a, n. d.)

Name of administrative region	Population	Land area (km²)	Density (inhab./km²)
Montréal	2 025 928	497	4076
Nord-du-Québec	46 673	701 031	0.0665
Nunavik	15 593	407 663	0.0382

This region is divided into three territories: Eeyou Istchee, Jamésie, and the Kativik regional government (KRG). The KRG[7] covers almost all of Nunavik (Institut de la statistique du Québec, 2021) and has jurisdiction over the region (Lacroix, n. d.). Kativik is the name sometimes used to describe the territory over which the KRG exercises authority. Eeyou Istchee is the territory reserved for the East Cree indigenous nation. It is divided into pieces, only one of which is located in Nunavik: the Whapmagoosti reserved land and village. This is the only land included in Nunavik that is not under KRG jurisdiction. Figure 3.1 shows Nunavik's location in Canada.

[7] Cette institution est aussi désignée par le nom francophone Administration régionale Kativik (ARK) dans ce document.

Figure 3.1 Nunavik among Canada's political divisions
Adapted from Natural Ressources Canada (2006)
Licensed under [Open Government Licence - Canada]

Nunavik's coasts are home to 15 indigenous communities: 14 Inuit and one Cree (Whapmagoostui). Among the Inuit communities, 13 consist of a village and adjoining reserved land managed by a landholding corporation. This is a legacy of the James Bay and Northern Quebec Agreement (JBNQA), which only the community of Puvirnituq has not signed and therefore has neither reserved land nor a landholding corporation (Koperqualuk, 2014, cited in Harbour-Marsan, 2018; Therrien and Duhaime, 2018). Inuit village populations, as highlighted in Tableau 3.2, represent the majority of Nunavik's inhabitants. As of 2023, the territory counted 15,775 inhabitants, 14,673 of whom lived in Inuit villages (Duhaime and al., 2021; MAMH, 2023).

Tableau 3.2 Area and population of villages and reserved lands in Nunavik
Taken from MAMH (2023)

Territory name	Total village area (km^2)	Village population (2023)	Total area of associated reserved land (km^2)
Akulivik	74.6	694	429.3
Aupaluk	28.7	235	523.2
Inukjuak	56.0	1972	409.4
Ivujivik	34.6	473	432.5
Kangiqsualujjuaq	33.9	1099	514.9
Kangiqsujuaq	11.2	905	552.0
Kangirsuk	54.6	608	506.3
Kuujjuaq	284	2825	319.3
Kuujjuarapik	7.02	763	281.5
Puvirntuq	79.9	1965	-
Quaqtaq	24.7	468	485.7
Salluit	14.3	1715	587.6
Tasiujaq	66.0	425	485.4
Umiujaq	25.4	526	250.8
Whapmagoostui	113	1102	205.0

3.3.2 Quebec's energy context

Power generation in Quebec is largely dominated by hydroelectricity, which accounts for around 89% of the 45,389 MW installed in the province in 2020. This share is installed in the first half of southern Quebec, where the power grid is dense and mixed with other modes of generation: wind farms in the southeast and, in places, stand-alone, almost exclusively diesel-engine thermal power plants. However, the grid does not extend beyond the 55th parallel, which forms a clear demarcation between northern and southern Quebec. In fact, there is no electricity transmission network north of this boundary: each power grid is autonomous, and was completely dependent on a diesel thermal power plant by the end of 2022 (Whitmore and Pineau, 2022). In fact, Nunavik is home to 14 autonomous grids, each supplying a village and its inhabitants with electricity for municipal, private and domestic needs; domestic needs excluding heating (see sections 3.5.3 and 3.6.2). The only exception is the Kuujjuarapik autonomous grid, which supplies not only the village of the same name, but also the Cree village of Whapmagoostui.

While hydropower accounted for 89% of installed capacity in Quebec in 2018, it covered 94% of electricity generation that same year (Tableau 3.3). Of this production, a total of 36 TWh was exported to several surrounding regions. On the other hand, 31 TWh were imported, including 29 TWh from Newfoundland and Labrador (Churchill Falls hydroelectric plant), whose electricity production is 96% hydroelectric (Régie de l'énergie du Canada, 2022; Whitmore & Pineau, 2022). Electricity produced and consumed in Quebec is largely based on renewable energies, and is among the lowest emitters of greenhouse gases (GHGs) in the world (Levasseur and al., 2021).

Canada produces almost 600 TWh of electricity each year, with Quebec being the most productive province with at least 200 TWh per year (Tableau 3.3) (Canada Energy Regulator, 2022a; Whitmore and Pineau, 2021, 2022, 2023). Thus, Canada ranks among the 10 countries with the highest annual electricity consumption per capita, at around 15 MWh per capita (Canada Energy Regulator, 2022c; The World Bank and IEA, n. d.). In Quebec, this consumption is 60% higher than the Canadian average, at 24 MWh per capita, placing Quebecers among the highest electricity consumers in the world. This contrast with the rest of Canada is mainly due to certain industries and residential heating, which relies in part on electricity (Canada Energy Regulator, 2022a).

However, Quebec is still largely dependent on fossil fuels, since petroleum products and natural gas together account for over 50% of the province's final energy consumption (Canada Energy Regulator, 2022a; Whitmore and Pineau, 2023). However, this is less than the Canadian average, which exceeds 75%, mainly due to electricity generation, which relies on natural gas, coal and even oil for nearly 20% of its output. While some provinces, such as Quebec, British Columbia and Newfoundland and Labrador, rely over 95% on renewable energy sources, others, such as Alberta, Saskatchewan and Nova Scotia, depend on fossil fuels for 90%, 81% and 76% respectively. Moreover, electricity consumption in the transportation sector is negligible compared to other sectors, since transportation relies on petroleum products

(Canada Energy Regulator, 2022c). In Quebec, petroleum products account for over 97% of transportation consumption (Whitmore and Pineau, 2022).

Tableau 3.3 Installed capacity and power generation in Quebec in 2018
Taken from Whitmore and Pineau (2023)

Means of production	Installed capacity (MW)	Power share (%)	Annual production (MWh)	Share of production (%)
Hydropower	40 438	89	194 580	94
Wind	3432	7.6	10 764	5.2
Biomass	797	1.8	1242	0.6
Solar	no data	-	2.1	0,0001
Fossil fuel combustion	722	1.6	830	0.4

Quebec does not produce crude oil, but can refine between 372 and 402 thousand barrels of oil per day (Canada Energy Regulator, 2022a; Whitmore and Pineau, 2022). The province sources its oil almost exclusively from Canada or the United States. In 2019, crude oil deliveries to Quebec were 63% from the United States and 37% from Canada, notably the West (MERN, 2020). In fact, 95% of Canadian production came from Western Canada, with the remainder coming mainly from Newfoundland and Labrador. In short, Alberta, Saskatchewan and Newfoundland and Labrador produce 96% of Canada's oil, making the country the world's fourth-largest producer (Canada Energy Regulator, 2022c). In 2020, Canada imported 555 thousand barrels of oil, 77% of which came from the United States. Despite these imports, Canada remains a net oil exporter, with exports approximately 6.5 times greater than imports in 2020 (Canada Energy Regulator, 2022b).

3.3.3 Nunavik's socio-economic context

There are fundamental and persistent differences between the socio-economic context of Nunavik and that of the rest of Quebec (Duhaime, 2004, 2007; Duhaime and al., 2021). First, populations differ. Nunavik's population is growing faster, and fertility and birth rates are two to three times higher than in Quebec as a whole. The population is also younger. In fact, 61.8%

of the population is under 30 and 3.6% over 65, compared with 33.8% and 18.3% respectively in Quebec. Finally, life expectancy is relatively low, at 69.7 years in Nunavik versus 82.4 years province-wide (Duhaime and al., 2021).

In addition, some social inequalities within the region, or in relation to the province, are to be considered. Firstly, significant income inequalities persist between Nunavik and the province, as well as between indigenous and non-indigenous populations within the territory itself (Duhaime and al., 2021; Imani and al., 2021; Robichaud and Duhaime, 2015). In Nunavik, the average income of non-indigenous individuals is more than twice that of indigenous individuals (Duhaime and al., 2021). However, average disposable income in the region is 14% lower than in the province. The gap between Nunavik indigenous people and the Quebec population is therefore even greater (Robichaud and Duhaime, 2015). Moreover, the unemployment rate reached 15.4% in 2016, compared with 7.2% in Quebec at the same time. Education levels also vary: 65.4% of indigenous people have no diploma, and only 5.5% have a higher education. For the non-indigenous inhabitants of Nunavik, these figures follow the opposite trend: 4.9% and 74.5% respectively. Finally, health and housing are issues whose control is uncertain. In Nunavik, mortality is twice as high as in Quebec, with certain diseases and suicides over-represented compared to the province. Infant mortality is seven times higher. As for housing, over 20% are in need of major repairs, and over 30% are overcrowded. (Duhaime and al., 2021) which could contribute to the deterioration in the respiratory health of their residents (Poulin and al., 2022; P. Robert, 2021).

The economy of Nunavik differs from that of Quebec. In particular, it is much less diversified: the mining, construction, and public administration sectors account for 85% of the GDP, of which nearly half is attributable to the mining sector (Robichaud and Duhaime, 2015). Thus, the mining sector and public administrations are among the main providers of regular employment alongside health and social assistance services, and educational services. However, it should be noted that a portion of regular jobs are occupied by non-residents, meaning workers coming from outside Nunavik but not residing there. Specifically, 85% of jobs in the mining sector are held by non-residents. As a result, almost 30% of Nunavik workers

- some of whom are still residents - are allochthonous. This explains why the GDP per capita is higher in Nunavik than in the rest of the province despite a lower disposable income. Indeed, the wages of non-resident workers are included in the GDP but do not contribute to the average disposable income (KRG, 2011; ISQ, 2020; Lévesque and Duhaime, 2021; Robichaud and Duhaime, 2015).

If it hasn't been mentioned yet, the tourism sector is nevertheless growing in Nunavik (ISQ, 2022). Moreover, it presents interrelations with the northern indigenous culture. Indeed, this sector is notably supported by the attractiveness of natural spaces and traditional practices, which also constitute cultural pillars for the communities (Antomarchi, 2010; Martin, 2012). In this context, the majority of adults in Nunavik engage in traditional activities such as hunting, fishing, trapping, and gathering wild plants (Duhaime and al., 2021). For example, Arctic char or caribou still represent important food sources for the Inuit (Auger and al., 2012, cited by Harbour-Marsan, 2018). In this sense, the natural environment plays a multifaceted role in Inuit cultural identity (Antomarchi, 2010; Martin, 2012; Robbe and Robbe, 2022). Nowadays, communities have to navigate between tradition and modernity in order to preserve this identity (Antomarchi, 2010; Létourneau, 2005). To do so, a controlled and environmentally respectful tourism seems to be one of the chosen avenues by the communities, as it serves as a means to both promote and preserve culture. Furthermore, this rationale appears to be a prevailing argument for the economic benefits derived from tourism (Antomarchi, 2010; T. Martin, 2012).

3.4 Recent development of energy production in Nunavik

3.4.1 Background on renewable energies and conversion of autonomous grids

In Canada, electricity production falls under the jurisdiction of the provinces. Thus, the state-owned company Hydro-Québec (HQ) holds a “quasi-monopoly on electricity transmission and distribution throughout the province” (Harbour-Marsan, 2018), including in Nunavik. And yet, for as long as they have existed, the region's means of generating electricity have relied entirely on petroleum products. In 2014, the entire region's hydrocarbon needs would have required the transport of around 195 million liters of fuel[8] (Comtois and al., 2019). As a result, HQ has been seeking for several decades to diversify its production methods in order to reduce its fuel consumption in Nunavik. Saulnier and Forcione (2004) presented a brief summary of the context in the early 2000s. To summarize, as early as 1986, the state-owned company and the energy sector began to study the possibilities of installing wind-diesel hybrids (WDH). In particular, experiments were carried out as early as 1987 to dimension a system (Saulnier and Ried, 1987). This was followed by a series of studies confirming the value of high-penetration[9] WDH, i.e. a system in which more than 50% of demand is met by wind power. In 1994, the technical feasibility of such a WDH project was demonstrated by IREQ[10] on the scale of 14 autonomous grids, a work endorsed by Reid and Saulnier (1998) a few years later. An economic feasibility study carried out in 1996 recommended an initial implementation of the technology. This was corroborated in 2004 by an economic evaluation report published by Hydro-Québec Distribution (HQD), at a time when all Nunavik's autonomous grids were still 100% diesel-powered. Based on the data available at the time, which was sometimes extrapolated or fragmentary, seven sites - out of sixteen - showed significant economic interest. In particular, two sites in Inukjuak showed promising profitability. It was therefore recommended to install a WDH in Inukjuak first, and to reallocate the project to other promising sites in the event of unforeseen circumstances, namely Kuujjuarapik or Kangiqsualujjuaq, or even Kangirsuk. Finally, other measures and work were to be produced in parallel on the three most interesting villages, leading to the installation of a pilot project (Saulnier and Forcione, 2004).

In its 2006-2010 strategic plan, HQ indicated that a pilot project was being studied in Inukjuak (HQ, 2006), but the village community rejected the project in favor of developing a hydroelectric project (HQD, 2011). In 2007, HQD was planning two other pilot projects: one

[8] Unclear data to be cross-referenced with other references.
[9] See Steve Drouilhet's classification of penetration rates in (Guérette, 2010)
[10] IREQ : Institut de recherche en électricité du Québec (Québec Institute for Research in Electricity)

in Kangiqsualujjuaq and the other in Akulivik (HQD, 2007). These sites were noted for their attractive economic profile (Saulnier and Forcione, 2004). HQD then planned to commission the first WDH in 2013 at Kangiqsualujjuaq, and the second in 2015 at Akulivik, following the construction of the new Akulivik thermal power plant (HQD, 2009). By 2010, the anemometer campaigns at Kangiqsualujjuaq and Akulivik were completed, and the business model for wind power in Nunavik was defined. However, the timetable changed: commissioning of the Kangiqsualujjuaq pilot project was to begin in 2015 at the earliest, and the Akulivik project would be launched at "the appropriate time" (HQD, 2010a). Then, HQD explained that the installation of a WDH in Akulivik would begin as soon as the one in Kangiqsualujjuaq was deployed (HQD, 2011). In 2013, the studies carried out in Kangiqsualujjuaq for the WDH were still in progress. Then, while they were described as promising (HQD, 2013), this project was halted in 2014 following ultimately unfavorable results (HQD, 2014).

In 2010, no other renewable energy projects was specifically planned for 2020, and eight power plants would probably have to be upgraded to meet growing demand. However, HQD's strategy is based on renewable energies: "To complement or replace thermal generation, Nunavik's supply strategy calls for the use of WDH and, eventually, hydropower or combined hydropower-diesel including tidal turbines" (HQD, 2010a). In fact, the technical solution of run-of-river submerged tidal turbines was studied (HQ, 2009), but was eventually set aside after a study of the Koksoak River site showed multiple weaknesses, constraints and uncertainties (HQD, 2013, 2014). In 2011, the Régie de l'énergie published an expert report in response to HQD's 2011-2020 supply plan. It points, in particular, to the lack of WDH deployment or pilot projects, which had been expected for 15 years, as well as the "continual variation" in the location of pilot projects. High-penetration WDH is said to be the cause of these delays, as the technology was too ambitious for the 2008-2017 timeframe, whereas low and medium-penetration WDH was already feasible and cost-effective (Deslauriers, 2011). In 2016, the various failures to deploy WDH prompted HQD to change its strategy, which was to call on the market by issuing calls for tender. However, this approach also failed. To go further, a discussion as to this "status quo" situation is presented by Harbour-Marsan (2018).

From 2013 onwards, the issue of GHG emissions appears in supply plans: HQD has now to purchase emission rights for power plants emitting more than 25,000 tons of CO_2 equivalent per year (HQD, 2013). Furthermore, HQD now includes the reduction of its “environmental footprint” as one of the two objectives in the conversion of autonomous grids, alongside the reduction of operating costs (HQD, 2016b). However, the scenarios primarily involve WDH for all grids except Inukjuak, where the community prefers hydropower. Nevertheless, another solution holds greater potential for reducing GHG emissions: connection to the integrated grid. While the complexity and estimated cost of such an undertaking on the scale of Nunavik have precluded the idea (see section 3.4.3), the situation in Whapmagoostui is unique. In 2002, the Crees of Québec, HQ, and the Société d'énergie de la Baie-James signed an agreement to connect Whapmagoostui to the integrated grid once the community was linked to the Quebec road network. This agreement follows another one signed in 1986 by the same parties, which outlined the connection of five Cree communities to the integrated grid. By 2010, Whapmagoostui was the only Cree community that had not yet been connected to the integrated grid and likely would not be connected by 2020 (HQD, 2010a). In fact, as of 2019 and 2022, this connection is still not in progress (HQD, 2019, 2022).

Similar to the Inukjuak grid, the Whapmagoostui/Kuujjuarapik grid is being developed by local stakeholders. In 2011, 5 kW of photovoltaic panels were installed on the rooftop of the community science center at the Centre for Northern Studies (Sirois, 2011, cited in Boisseau-Bouvier, 2019). During the same year, the Whapmagoostui First Nation (WFN) took the lead on a hybrid power plant project for the Whapmagoostui/Kuujjuarapik grid. It then created the company Nimschu Iskudov to develop this project (WFN, 2012; Nimschu Iskudow, n. d.). In 2013, Nimschu Iskudow and the Inuit corporation Sakkuq Lanholding entered into a partnership (KWREC, 2020). Subsequently, investments from the Quebec government and several Chinese companies propelled the project forward (German, 2014). Various production approaches were then examined (Nimschu Iskudow, n. d.). For instance, a study funded by the Canadian government's ecoENERGY Innovation Initiative and overseen by Nimschu Iskudow underscored the technical and economic viability of two variations of the same system. This involved integrating three 1.5 MW wind turbines with a diesel generator and a battery. One of the variations also integrated a biomass generator. This system, capable of supplying both communities, underwent negotiations for power purchase agreements with HQ (Nimschu Iskudow, 2014; Natural Ressources Canada, 2014). Subsequently, the project was presented to the Régie de l'énergie in 2014 and again in 2017, which then recommended that HQD collaborate with both the Cree and Inuit communities to ensure the project's alignment with the interests of both parties (Nimschu Iskudow, n. d.). Morin and al. (2017) provide an overview of the situation at that time. Recent developments in this project are outlined in the following section.

In summary, the main technology being considered in Nunavik is WDH, with the exception of Inukjuak, where the community prefers a hydroelectric project. However, in 2011, the Régie de l'énergie pointed out that solar photovoltaic was now cost-effective - as competitive, if not more so, than diesel - and recommended that HQD now pursue the possibilities offered by this technology (Deslauriers, 2011). Yet the 2014-2023 and 2017-2026 supply plans make no mention of photovoltaic power, or of any use of solar energy (HQD, 2013, 2017).

3.4.2 Development of grids and renewable energy sources from 2017 to the present date

In 2017, Tarquti Energy (hereinafter Tarquti) was created as a joint venture between the Makivik Corporation and the Fédération des coopératives du Nouveau-Québec[11] (FCNQ). Tarquti embodies the desire of the Inuit people to play a role in Nunavik's energy transition (Harbour-Marsan and Lasserre, 2021), and in particular in the deployment of renewable energies. This new player, expected to facilitate the conversion of autonomous grids, is a new interlocutor for HQD, which plans to set up a “global agreement” (HQD, 2018). From then on, the two players cooperated on wind power projects and the Inuit company installed wind measurement towers in five villages (HQD, 2021a). More specifically, these five weather

[11] FCNQ is a group of 14 member cooperatives from the Inuit communities of Nunavik. It has a dozen subsidiaries and partners, including FCNQ Petro Inc. and Nunavik Petro Inc.

masts were installed in 2021 in the communities of Puvirnituq, Salluit, Kangiqsujuaq, Quaqtaq and Kuujjuaq (Tarquti, n. d.). Then, in 2022, Tarquti became HQD's official partner for the development of renewable energies in Nunavik, with the exception of the Whapmagoostui/Kujjuarapik and Inukjuak grids (HQD, 2022). The arrival of this player appears to be the impetus for a new dynamic in Nunavik's energy transition (Hoicka and al., 2021; Rodon and al., 2021; Stefanelli and al., 2019). Also, a study currently underway is assessing the opportunities for installing solar panels on institutional, commercial or residential buildings. In addition, a broader research project - in partnership with Nergica and HQ - has been launched on the question of renewable energy implementation in Nunavik (Tarquti, n. d.; Picard, 2022). Finally, the following paragraphs present recent developments in the means of energy production in the various communities of Nunavik.

Tasiujaq

With the Tasiujaq thermal power plant reaching the end of its service life, it is among those whose replacement is becoming necessary (CQEK, 2019a). While several proposals had already been received for the Tasiujaq power plant replacement project, a call for proposals was issued in the fall of 2018. It was subsequently planned that the future thermal power plant would be hybrid and incorporate solar energy. In any case, its more recent diesel engines are expected to reduce fuel consumption[12] by 15% (HQD, 2017, 2018). It is also suggested that increased integration of renewable energy could follow in partnership with Tarquti (HQD, 2018, 2019). The plant is expected to incorporate three generators, each rated at 575 kW, as well as a set of solar panels whose output is unspecified, but is expected to account for 2% of the plant's total output (CQEK, 2019). The plant was due to come on stream in December 2022, but will eventually be commissioned in 2023 or even 2024 (HQD, 2019, 2022).

[12] This reduction in consumption is likely to apply to the same output from the old power plant. In fact, as the new power plant is more powerful, it is likely to consume more, despite its greater efficiency (CQEK, 2019).

<u>Puvirnituq</u>

Also at the end of its life, the Puvirnituq power station needs to be replaced. It has already undergone a planning study and an environmental assessment, and could be commissioned by 2026-2027. With a design life of 50 years, it should be equipped with two 1.86 MW generators and two 1.39 MW others. This first scenario would lead to a total installed capacity of 6.5 MW, but a second scenario would bring it up to 7.44 MW, or even 7.5 MW (CQEK 2022b; HQD, 2021b). Thereafter, it is possible that the plant could be upgraded to 9.30 MW. The current plan is for the thermal power station to meet its own needs via solar panels and an engine heat recovery system. It could also be combined with a wind farm to reduce GHG emissions and increase profitability. In this way, an installed wind power capacity of 6 MW and a 3 MW battery should take over a share of production in the future: 46 to 62% of production in 2027. Other projects had been discussed: an expansion of the existing power station, which would have been economically and technically risky, or the construction of an 8.1 MW hydroelectric power station whose profitability potential was too low and which the Puvirnituq municipal council rejected (CQEK, 2021c; HQD, 2021b).

<u>Quaqtaq</u>

Elsewhere, a new project appeared in the 2017 progress report of the 2017-2026 supply plan: a pilot project for the deployment of solar energy on the Quaqtaq grid (HQD, 2017). This project, which brought together 69 solar panels and a total installed capacity of 20.4 kW, was commissioned in winter 2018 (HQD, 2018, 2019; HQ, n. d.-a). This installation was backed up by 1,000 kWh of electrochemical storage capacity supplied by two EVLO 500 arctic systems (EVLO, 2020). On the other hand, a second pilot project - including a 600 kWh battery - came on stream at the end of 2018 (EVLO, 2023b), before a third pilot project went live in September 2019. The latter, supported by the Société d'habitation du Québec (SHQ) and Transition énergétique Québec (TEQ), installed 24 kW of solar panels on the roofs of four residences (20 panels of 300 W per roof), as well as batteries in them. Four panel technologies and three battery manufacturers were being tested (HQD, 2019; SHQ, 2019). These projects were still underway (HQD, 2021a), but have not been mentioned since 2021 (HQD, 2022).

Inukjuak

In Inukjuak, the community's preference for hydroelectricity, expressed as early as 2011 (HQD, 2011), is becoming a reality: at that time, HQD, the Inukjuak Pituvik Landholding Corporation and Innergex are discussing a project with an installed capacity of 7.5 MW. With such a facility, the local community would be able to use electricity as a primary source of water and space heating without tariff disincentives (see 3.6.2) (HQD, 2018). In June 2019, a supply contract is submitted for approval (HQD, 2019) and will be signed and approved within the year (Innergex, 2019). This paves the way for the dual-energy tariff (see 3.6.1 and 3.6.2) (CQEK, 2019; HQD, 2022). Construction of the plant began in the summer of 2020 and was scheduled to start up in December 2022 (HQD, 2021a), but was not scheduled to start up until 2023 (HQD, 2022), a priori in the third quarter (Innergex, 2023). The will and participation of the community are highlighted as important levers for the development of this project (CQEK, 2019; HQD, 2018). To offset any problems with this new production method, a new backup thermal power plant with a capacity of around 6 MW is due to come on stream in 2024. This is being built solely to ensure system reliability in the event of maintenance or failure of the hydroelectric plant (CQEK, 2021).

Whapmagoostui / Kuujjuarapik

In February 2019, discussions between Nimschu Iskudow and Sakkuq Landholding led to the creation of a joint steering committee and, in June 2020, the Kuujjuaraapik Whapmagoostui Renewable Energy Corporation (KWREC). This company, owned equally by Whapmagoostui Eeyou and Kuujjuaraapik Inuit, became the sole developer of the project projet (KWREC, 2020, 2022; Nimschu Iskudow, n. d.). From then on, stakeholders submitted several wind farm projects. The first aimed to install three wind turbines worth a total of 2.4 MW (PESCA environnement, 2020). Then a second project - the latest to date - aimed to install two wind turbines of 1.5 MW each, and had already been the subject of several environmental and social impact studies (COMEX, n. d.; KWREC, 2022; PESCA environnement, 2021). In 2023, a supply contract should be submitted to the Régie de l'énergie, one of the last steps before the project becomes a reality (HQD, 2022). The system is scheduled for commissioning in December 2023 (HQD, 2019, 2020, 2021a). In addition, a 900 kW / 900 kWh battery system has been installed to facilitate the absorption of peak demand and the integration of solar energy (EVLO, 2023a).

However, population growth should lead HQD to install a fourth 1880 kW generator at the grid's thermal power station. Initially scheduled for 2023, this power increase should be effective by 2024-2025, raising installed capacity to 5,285 kW. Until then, a mobile generator will ensure grid reliability (CQEK, 2021b, 2022; HQD, 2022). Other sources of renewable energy could be explored in the future and complement the replacement of the current thermal power plant, which would ultimately serve only as an emergency source (Nimschu Iskudow, n. d.). In particular, a biomass component could be added to the production complex (ICI.Radio-Canada.ca, 2022). Furthermore, a biomass cogeneration project was financed in 2017 by Fonds Biomasse Énergie, aiming for developer Nimschu Iskudow to convert the Whapmagoostui sports complex to residual forest biomass (Fondaction, 2017; HQD, 2018; YAB Management, n. d.). Since then, the Whapmagoostui greenhouse and sports center have benefited from a conversion to biomass heating and cooling thanks to the ecoENERGY program for indigenous and northern communities. This has improved their energy efficiency and contributed to more sustainable solutions for the community (Comité Transition énergétique Québec and al., 2020).

Kangiqsujuaq

The replacement of the region's oldest power station - at Kangiqsujuaq - is scheduled for 2027-2028. The new plant will be equipped with three factory-refurbished generating sets, rated at 855 kW, 1135 kW and 1168 kW, giving a total installed capacity of 3.16 MW at commissioning. This can be increased to 4.6 MW by adding a fourth generator set as required. In addition, photovoltaic panels with a capacity of up to 20 kW will be installed on the power plant building. The design will also allow for the future integration of a wind farm of around 2.3 MW (CQEK, 2022e; HQD, 2022).

Brief conclusion

In Kuujjuaq, a total of 70 kW of photovoltaic panels have been installed: 20 kW on the roof of the Makivik Corporation premises and 50 kW on the roof of the Nunavik Research Centre. Otherwise, Nunavik's other autonomous grids supplying communities do not appear to have any renewable energy projects at the moment[13] (Belmokhtar and Durette, 2021; Makivik, 2017). Figure 3.2 summarizes the status of the generation systems of each autonomous grid. However, each of them is bound to evolve in line with growing demand and the state of the generation infrastructure. Further information on this subject can be found in section 3.5.1. On the other hand, other technologies may be deployed in the region in the future. An overview of the prospects is given in paragraph 3.4.3. Finally, the mining sector has not yet been dealt with, as a specific section has been devoted to it (see section 3.5.2). This helps to put the energy development of communities into perspective.

[13] Government follow-up seems to exist, but is rarely mentioned (Ministère de l'Énergie and des Ressources Naturelles (MERN), 2021).

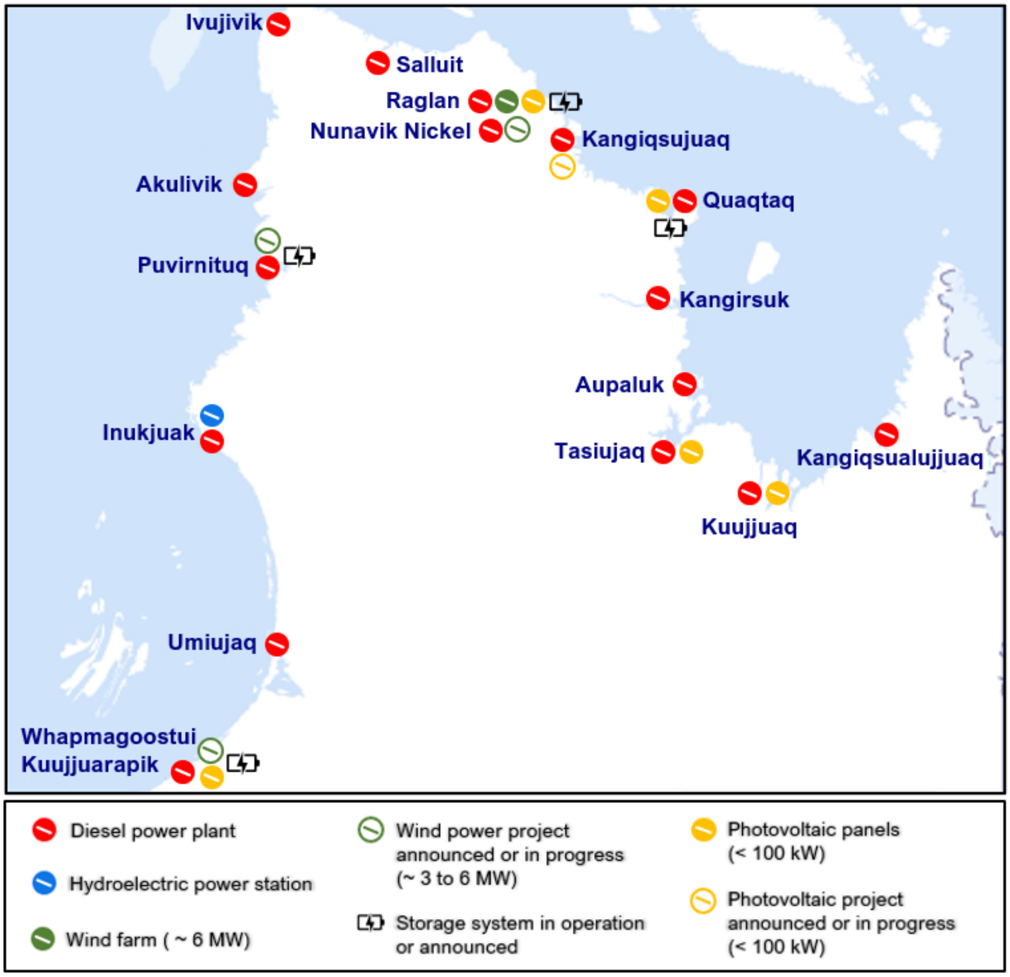

Figure 3.2 Map of autonomous grids
Adapted from HQ (2023a)

3.4.3 Other integrations and energy perspectives

Belzile and al. (2017) present an overview of the potential of renewable energies in northern Quebec and the constraints they may face. However, the more recent literature presents new advances and some projects are developing or even reaching fruition. This section therefore proposes new keys to understanding Nunavik's energy prospects, based on this literature.

<u>Electricity generation: wind power and photovoltaics</u>

Belzile, Comeau, and al. (2017) present four primary energy sources for generating electricity: wind power, solar radiation, biomass, and water power. Firstly, Nunavik has great wind potential, but the deployment of turbines to capture it faces several obstacles. For one thing, freezing temperatures may require wind turbine blades to be heated[14], or even shut down below a certain temperature. In addition, the characteristics of projects designed for northern communities limit the profitability of these installations. These projects are expensive because of their isolation or permafrost, and their relatively small size limits economies of scale. Zuliani and al. (2021) explain that the cost of an average wind power project (40 MW) in the isolated northern regions of Canada is two to three times higher than a large-scale project in the more active southern regions. However, this work also points to favorable economic prospects, thanks in particular to electrical energy storage. This issue is studied for several technologies (Azin, 2022; Robert, 2023; Tardy, 2022). Overall, wind power deployment in northern environments has been a very active field of study since the 1980s and remains so today[15]. An entire literature review could be devoted to it.

Similarly, this region has a photovoltaic potential enhanced by low temperatures, which increase the efficiency of photovoltaic cells, although snow cover can cause losses (Frimannslund and al., 2022; Pawluk and al., 2019). These potentials are detailed and illustrated in a state-of-the-art report by HQ (HQ, 2021b, 2021c). In parallel, the results of Das and Cañizares (2019) suggest that relatively low investments would enable the implementation of these technologies and that they would contribute to a substantial reduction in CO_2 emissions. More specifically, this study proposes a pre-selection of communities likely to integrate renewable energies and suggests that these integrate hybrid systems combining photovoltaic or wind power with diesel and variable-speed generators.

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[14] This is the case for the wind turbines installed at Raglan and Nunavik Nickel's future wind turbines (see 3.5.2).

[15] See, for example, the publications of A. Ilinca (https://scholar.google.ca/citations?user=DDFQllIAAAAJ&hl=fr)

Electricity generation: hydropower

It is estimated that Nunavik's hydroelectric resources would be capable of generating 6300 to 7200 MW (KRG, cited in Karanasios and Parker, 2017) or even up to 8000 MW (KRG & Makivik, 2010). Yet few studies have been conducted on the deployment of this technology in northern Canada. The work of Karanasios and Parker (2017) already highlighted this a few years ago. In fact, there are economic, environmental and socio-cultural factors holding back hydroelectric development. These are particularly marked for hydroelectric dams, and moderately marked for run-of-river plants (Paquet and al., 2021). In both cases, there are concerns about the impact of these infrastructures on the environment and biodiversity (Makivik and al., 2014; Paquet and al., 2021; Parnasimautik, 2013). In addition, other economic constraints could exert an influence. For example, the return on investment seems to vary significantly from one project to another (Cherniak and al., 2015). On the other hand, diesel substitution is not good business for all energy players in Nunavik. Indeed, the sale of petroleum products generates revenues and jobs, and the case of the Inukjuaq hydroelectric project generates other economic considerations (CQEK, 2019; Makivik and al., 2014).

Another technology would harness the kinetic energy of water. The tidal power potential of Ungava Bay greatly exceeds the electricity demand of the four Inuit communities in the region, with an approximate electricity-generating capacity of 5 MW. In fact, river currents alone have a potential that far surpasses the energy needs of these communities. Furthermore, these communities benefit from their proximity to major rivers. On the other hand, the theoretical potential of tidal currents could be as high as 4,200 MW in the region, over a hundred times greater than the current power generation capacity of Nunavik communities. Additionally, four of the identified sites are situated within 15 kilometers of the four villages in the region. However, the ecological impact of these technologies is still a subject of debate (HQ, 2021c).

Electricity generation: less CO_2-emitting thermal power plants

In the meantime, certain lesser-discussed fuel options have emerged in the literature. To begin with, biomass is predominantly highlighted as a heat source rather than an electricity producer in Nunavik, although counterexamples can be found in northern Canada. Nonetheless, the utilization of this energy source is limited by the availability of forest residues beyond the tree line (Belzile and al., 2017). Conversely, the technical, economic, and environmental aspects of transitioning from diesel to liquefied natural gas (LNG) are explored by McFarlan (2020). In terms of economics and greenhouse gas emissions, LNG could offer competitiveness similar to wind-diesel hybrid systems (WDH) with a wind penetration rate of 25%. While LNG generally emits significantly fewer CO_2 emissions compared to diesel, it also presents other technical and environmental considerations that warrant discussion depending on the context (Belzile and al., 2017). A comparable analysis is conducted for biofuels, specifically methanol and dimethyl ether. This analysis concludes that the electricity production costs would be higher compared to diesel-based methods, yet still comparable. However, the biofuel-based production would result in significantly lower greenhouse gas emissions, eliminating the need for purchasing pollution rights, unlike diesel (McFarlan, 2018).

Electricity generation: nuclear power

Finally, small modular nuclear reactor technology is also being considered as an alternative to diesel power in isolated stand-alone grids. In particular, this technology could be coupled with renewable energies to offset their intermittency and thus limit the need for electricity storage (Gabbar and Esteves, 2022; Michaelson and Jiang, 2021). However, the economic viability of this technology is debated in the context of northern Canada. In fact, Froese and al. (2020) explain that it would be too costly at present to invest in this technology, which does not yet have a sufficiently developed market in the region. However, these results do not converge in the literature. In some cases, this technology could be as competitive, or even more so, than diesel and renewable energies, according to Lovering (2023). Moreover, the case of isolated mines is qualified by Bayomy and al. (2023). Integrating this technology with renewable energies would significantly reduce greenhouse gas emissions and would be economically viable. Innovations could simplify such coupling, while limiting the investment required (Gabbar and Esteves, 2022).

Electricity supply: the grid connection solution

On a completely different scale, other possibilities have been studied to connect communities to hydroelectric resources. The first scenario involved connecting the villages as well as the Raglan complex to Quebec's integrated grid through a 2850-kilometer transmission line. This operation would have cost $1.6 billion. The second scenario involved building hydroelectric facilities in Nunavik and connecting them to the same isolated grids. This operation would have cost $890 million and taken 14 years. The Nunavik Plan suggested that such a connection could begin with the Kuujjuaq and Kuujjuarapik connections, which would then serve as pilot projects. However, these costs and the complexity of the projects make them unfeasible (KRG and Makivik, 2010; Makivik and al., 2014; Parnasimautik, 2013).

Heat pumps and geothermal energy: Northern Quebec's potential

Heating water and spaces is another major energy challenge in Nunavik. To address this, several technological fields are presented by Belzile and al. (2017), including heat pumps and specifically geothermal systems. In particular, their work compares different types of heat pumps, highlighting air-source heat pumps and geothermal heat pumps. The latter are available in the form of vertical boreholes or horizontal loops. A geothermal system of the latter type has been installed in Nunavik as part of a pilot project aimed at heating the municipal pool in Kuujjuaq. This would be the first of its kind installed in the arctic or subarctic regions of Canada (Giordano and Raymond, 2020). In this form or another, geothermal energy would present a competitive alternative to oil-based products for heating needs. Application examples are described for Kuujjuaq and Kuujjuarapik, with several approaches in existence (Nicolò Giordano and al., 2020). In particular, the findings of the study by Gunawan and al. (2020) indicate that shallow geothermal systems, especially when combined with photovoltaic energy, are the most economically attractive technology in Kuujjuaq. Moreover, it provides the opportunity to store heat in geothermal wells (Belzile and al., 2017) and recover up to 60% of it, as demonstrated by a case study conducted for this community (Giordano and Raymond, 2019). Additionally, the geothermal potential of the village of Kuujjuaq is further explored by Miranda and al. (2018), and Miranda and al. (2021), especially for deep geothermal systems by Valentina and al. (2018), Miranda and al. (2020), Miranda (2021), Miranda and Raymond

(2022), and Miranda and al. (2023). The case of shallow geothermal systems in the Whapmagoostui-Kuujjuarapik communities is described and investigated by Giordano and al. (2020).

Heat pumps and geothermal energy: additional perspectives

Moreover, the economic and environmental balance of heat pumps can be more advantageous if they operate in combination with other renewable energies (Belzile and al., 2017; Gunawan and al., 2020). In particular, one study simulated the operation of a solar-assisted ground-source heat pump with battery. The results show a reduction in domestic fossil fuel consumption for heating of around 60% (Maranghi, 2022; Maranghi and al., 2023). In addition, Langevin (2022) shows that above a certain level of photovoltaic assistance, ground-source heat pumps and geothermal storage are more relevant than other solutions. In addition, a SWOT analysis assesses the potential for integrated development of geothermal energy with other energy sources, including renewable energies. It concludes that geothermal energy systems offer the best alternative to diesel, particularly if they integrate other technologies and energy sources (Mahbaz and al., 2020). However, geothermal energy can weaken soils due to freeze-thaw cycles caused by pumping or heat storage, which can lead to incidents. Heat pumps, on the other hand, can help keep permafrost below freezing, which is beneficial in the face of climate change that is warming soils in the region (Belzile and al., 2017). That said, coupling a geothermal heat pump and solar thermal collectors would limit the impact on the soil by reducing the size of the boreholes drilled for geothermal energy. Although costly, this solution would also save energy (Kegel and al., 2016).

Other forms of heat generation

While geothermal energy holds promise, other renewable sources could also be implemented to generate or manage the required amount of heat for isolated communities. Specifically, thermal solar collectors are capable of heating water and air and can be installed in northern regions (Belzile and al., 2017; Cherniak and al., 2015). However, cold temperatures pose a challenge for this technology as they risk freezing the heat transfer fluids used (Belzile and al., 2017). On the other hand, biomass usage can be relevant for residential heating. A multi-criteria analysis based on a household in Kuujjuaq highlights wood pellets as the best option compared to other fuels (Yan and al., 2019; Yan, 2018). The return on investment for this technology is compared with others in a study by CCHRC (2015), cited by Belzile and al. (2017) More broadly, the impact of government incentives on the use of biomass as an energy source is explored by Vazifeh and al. (2023).

Domestic heating needs could also be met through district heating systems. By utilizing heat recovery from power plants, surplus renewable electricity, or an oil boiler, Pike and Kummert (2022) explore various scenarios for the communities of Whapmagoostui and Kuujjuarapik. Their findings indicate the feasibility and advantages of district heating. Notably, heat recovery from power plants could address 55% of the heating requirements. The utilization of surplus renewable energy is also energetically and environmentally interesting, although it is not yet cost-effective. Additionally, the valorization of waste or organic residues holds potential for heat production, usable for both heating and electricity generation (Belzile and al., 2017). Indeed, the heating demand for certain public buildings in Kuujjuaq could be met by this energy source (Ramboll, 2019 cited by Boisseau-Bouvier, 2019). Furthermore, for industrial purposes, recovering heat from small modular nuclear reactors could be considered if they were to be introduced to the region (Michaelson and Jiang, 2021).

Building energy efficiency

Furthermore, the efficiency of buildings, infrastructure, and the technologies integrated within them also holds potential for reducing fossil fuel usage (Belzile and al., 2017). Firstly, the geometry of buildings plays a role in reducing the energy demand for heating. Building profiles can be optimized based on bioclimatic principles that consider their compactness, orientation, and aerodynamics. Compactness and aerodynamics, in particular, significantly decrease thermal load, and the combination of these factors can lead to a 33% reduction in the best cases. Additionally, solar gains can be maximized (Lemieux-Montminy, 2022). On the other hand, effective building envelope insulation and more efficient heating methods provide further avenues for energy demand reduction. Concerning this, while various technical solutions have been discussed, others like radiant heating or heat storage in water tanks offer advantages

(Belzile and al., 2017). Finally, infrastructure efficiency partly depends on regulatory frameworks. A study highlights the role regulation can play in enhancing energy efficiency in northern Canadian buildings (Thirunavukarasu and al., 2018). To practically assess and optimize the efficiency potential of future constructions, a prototype of a northern dwelling has been built in Quaqtaq and is still undergoing testing (SHQ, 2020).

Efficiency, geothermal energy and thermal storage applied to greenhouse cultivation

The study of community greenhouses optimized for the northern context has seen significant development in recent years. In particular, a community greenhouse in Kuujjuaq has been undergoing measurements and improvements since 2016. A thermal storage solution was implemented in 2018 and numerically modeled to minimize temperature differences between day and night. This variation poses a constraint on extending the growing period due to low nighttime and cold-month temperatures (Piché, 2021; Piché and al., 2019, 2020). In this regard, the use of geothermal energy, either as a heat source or storage solution, has the potential to enhance yields (Mahbaz and al., 2020). Consequently, further thermal storage solutions are being explored, notably for seasonal storage. Horizontal underground storage proves more efficient than vertical storage, although optimization of the heat transfer fluid circulation is still required. However, coupling daily and seasonal storage systems shows promising economic viability (Giordano and al., 2021). Recent efforts continue to optimize greenhouse operations. Specifically, a model integrating the greenhouse and its thermal storage system is being developed (Maheux and al., 2023). Community greenhouses hold multi-faceted potential as outlined in the interdisciplinary approach undertaken by Lamalice and al. (2018). Their work highlights the social, environmental, and economic benefits of these infrastructures while also discussing their limitations. To delve deeper, Gaudreau and al. (2023) provide further contextual elements and a technoeconomic review of these structures.

Partial conclusions

Ultimately, several technologies hold the potential to reduce Nunavik's reliance on fossil fuels and the associated greenhouse gas emissions for electricity and heat production (Stringer and Joanis, 2023). Particularly, the realization of pilot or long-term projects in wind energy or geothermal energy suggests that the conditions for their deployment are already favorable or will be soon. Other, less discussed systems also offer intriguing potential but lack concrete project plans. Nevertheless, the implementation of such technologies is not solely a technical matter. Their environmental and social impact must be assessed, and communities must be consulted to validate projects: "In all cases, potential projects must receive a positive reception from the communities" (HQD, 2010a). While this aspect of acceptance and perception is not addressed in this work, it is discussed by Paquet and al. (2021) and Paquet (2022), who provide, among other things, a graphical representation of electricity production technology perception (Tableau 3.4). On the other hand, revenue from energy sales poses an economic barrier. The sale of petroleum products generates income and jobs. Therefore, their substitution is viewed negatively by some energy stakeholders in Nunavik (CQEK, 2019; Makivik and al., 2014). These issues are also elaborated upon by Harbour-Marsan (2018) and Harbour-Marsan and Lasserre (2021).

Tableau 3.4 Inuit and southerners interest in energy projects in Nunavik
Taken from Paquet and al. (2021)

		Diesel	Wind power	Solar panels	Hydroelectricity (dams)	Hydroelectricity (run-of-river)	Connexion to Quebec's grid	Other alternatives
Land cosmos *Respect for the land and the environment and fight against climate change/adaptation to its impacts*	*Inuit*	Red	Yellow	Green	Red	Yellow	Yellow	Grey
	Southerners	Red	Green	Teal	Red	Yellow	Green	Green
Social cosmos *Respect for traditional activities, quality of life and harmonization of spatial use*	*Inuit*	Yellow	Yellow	Green	Red	Yellow	Yellow	Grey
	Southerners	Yellow	Green	Green	Red	Yellow	Green	Yellow
Economic cosmos *Local economic benefits and economic viability*	*Inuit*	Green	Yellow	Yellow	Grey	Yellow	Red	Grey
	Southerners	Red	Green	Green	Red	Yellow	Red	Red
Governance *Decision power in planning and local management*	*Inuit*	Green	Yellow	Yellow	Red	Yellow	Red	Grey
	Southerners	Green	Green	Green	Grey	Green	Red	Grey

Outcomes are color-coded. Green: positive or neutral outcomes, yellow: moderately negative outcomes, red: strong negative.

3.5 Overview of energy production and consumption

3.5.1 Power generation for Nunavik communities

In total, there are fourteen autonomous grids operating in Nunavik to serve the 15 communities that live there. HQ defines an autonomous grid as “an electricity generation and distribution grid owned by HQ, but separate from the main grid. At the heart of each of these grids is a generating station from which electricity is supplied to one or more communities” (HQ, 2021). In Nunavik, autonomous grids are mostly built around thermal power plants. These would consume more than 25 million liters of fuel per year (Comtois and al., 2019). The fuel used in each of the power plants is a diesel adapted to northern regions, known as “artic diesel” or “arctic diesel”, which is supplied by FCNQ (HQD, 2016a, 2022). In fact, it supplies 11 of Nunavik's 14 power plants under the name FCNQ Petro, while the other three (Kangiqsualujjuaq, Kuujjuaq, and Quaqtaq) are supplied by Nunavik Petro, a subsidiary of the association (FCNQ, 2018; HQD, 2010a, 2019). Overall, FCNQ has a monopoly on the distribution of petroleum products in Nunavik (Harbour-Marsan and Lasserre, 2021; HQD, 2010a). In Nunavik, the 14 power plants had a total installed capacity of 34,269 kW in 2021 and generated 96.1 GWh of electricity in the same year. Tableau 3.5 and Tableau 3.6 show, respectively, the characteristics of each grid's generation infrastructure and a balance sheet of production in 2021.

Of the 89.15 GWh sold in 2021, just under half went to residential customers, i.e. 43.00 GWh HQD, 2022). This trend is confirmed by ECONOLER & HQD (2019), who show that 45% of consumption is attributable to tariff DN, i.e. residential customers, while the remaining 55% is attributable to the other tariffs, i.e. commercial and institutional customers (see section 3.6.1 for more information on tariffs). Tableau 3.6 details electricity production and sales for each grid.

Tableau 3.5 Characteristics of production equipment in Nunavik in 2021
Taken from HQD (2022)

Village supplied	Installed capacity (kW)	Year of construction	Efficiency (kWh/L)	Capacity factor	Guaranteed power (kW)
Akulivik	2 019	2015	3.79	59	1 163
Aupaluk(1)	960	Before 1981	3.60	62	576
Inukjuak	3 758	Before 1981	3.92	52	2 331
Ivujivik	1480	1985	3.50	56	657
Kangiqsualujjuaq	2 270	1986	3.80	56	1 274
Kangiqsujuaq(1)	1 529	Early 1970s	3.66	55	872
Kangirsuk	1 460	1987	3.45	68	810
Kuujjuaq	6 010	2010	3.94	58	4 327
W-K(1) (2)	3 405	Before 1981(3)	3.76	59	2 043
Puvirnituq	4 750	Before 1981	3.84	57	2 583
Quaqtaq(1)	1 085	1987	3.46	59	617
Salluit(1)	2 878	1990	3.75	57	1 539
Tasiujaq(1)	850	Before 1981	3.55	57	477
Umiujaq	1 815	1988	3.69	53	864

(1) The grid is supported by a mobile generator whose power is not included in this table.
(2) Whapmagoostui and Kuujjuarapik common grid.
(3) Partly rebuilt in 2002 after a fire.

The Nunavik demographics described in section 3.3 allow us to calculate annual electricity consumption per capita. For the region as a whole, this would be 5651 kWh for all sales, or 2726 kWh for residential customers alone. This customer base is the largest in terms of number of subscriptions, but it is mainly managed by the Kativik Municipal Housing Bureau, making this institution one of HQD's biggest customers. The rest of the production is sold to other public-sector entities such as KRG, the Kativik school board and Makivik, as well as to the private sector. However, sales can be broken down according to several structuring tariffs, which are presented in 3.6.1.

Tableau 3.6 Nunavik's electricity production and sales in 2021
Taken from HQD (2022)

Village supplied	Generation (GWh)	Plant consumption, losses and internal use (GWh)	Sales (GWh)
Akulivik	3.5	0.3	3.2
Aupaluk	2.4	0.2	2.2
Inukjuak	11.2	1.2	10.0
Ivujivik	2.6	0.2	2.3
Kangiqsualujjuaq	4.9	0.3	4.5
Kangiqsujuaq	5.1	0.3	4.8
Kangirsuk	4.2	0.3	3.8
Kuujjuaq	20.0	0.8	19.2
W-K	12.1	1.0	11.1
Puvirnituq	11.8	0.5	11.3
Quaqtaq	3.0	0.3	2.8
Salluit	9.4	1.0	8.4
Tasiujaq	2.6	0.2	2.5
Umiujaq	3.3	0.3	3.0
Total	96.1	6.92	89.2
As the values have been rounded, the total of each column may not correspond exactly to their sum.			

The desire of Nunavik's energy system stakeholders to convert autonomous grids to production methods independent of petroleum products is not the only reason for installing new infrastructure. The distribution company, HQD, also has to ensure security of supply, and the growing demand on the region's grids sometimes requires it to increase capacity. These operations are coordinated so that a reliability criterion is always met. This criterion is violated when the peak demand - which is highest in winter - exceeds the grid's guaranteed capacity C_g, calculated according to equation (3.1). In practice, HQD uses demand forecasts to anticipate this and increase the grid capacity before it happens (HQD, 2022).

Let C_{total} be the total installed capacity of the electrical grid.
Let C_{max} be the capacity of the most powerful generating unit.

$$C_g = (C_{total} - C_{max}) \cdot 90\% \tag{3.1}$$

Nowadays, if no renewable project is on track to increase guaranteed power, the necessary adjustment can be made in three different ways. In the short term, HQD can deploy mobile generators to avoid a power deficit. Each year, several such units are deployed in Nunavik: five in 2019, four in 2020, five in 2021, and six in 2022 (HQD, 2019a, 2019a, 2021a, 2022). In the long term, guaranteed power adjustment can be achieved by increasing the capacity of existing plants or replacing them with new ones. However, Tarquti has yet to announce any new renewable generation capacity in the region. Moreover, almost no projects on a scale similar to those at Inukjuak or Whapmagoostui/Kuujjuarapik are currently being discussed or are at an advanced enough stage to appear in Hydro-Québec's supply plans. Only a WDH project at Puvirnituq has advanced in recent years (HQD, 2021b). Thus, several additions or renewals of generating units and thermal power plants should take place in the coming years (HQD, 2022).

Following the completion of the new Akulivik thermal power plant in 2015, the Tasiujaq, Puvirnituq, Aupaluk and Kangiqsujuaq power plants are nearing the end of their useful lives and will also need to be replaced. The replacement plants are expected to be in service by 2023-2024, 2026-2027, 2027-2028 and 2028-2029 respectively. These are described in more detail in section 3.4.2. To meet demand, the new plant in this grid should have an installed capacity of 1975 kW (CQEK, 2023) : the project is currently under evaluation (HQD, 2022). It is also the subject of several tenders planned and launched in 2023-2024, along with the Kangiqsujuaq power plant project (HQ, 2023). In addition, seven capacity expansions are planned for existing power plants between now and 2030. To date, the size of these increases has only been announced for Salluit and Kuujjuarapik, which are the first plants to be affected chronologically. At Salluit, the replacement of two generators will increase the installed capacity to between 4768 kW and 5168 kW (CQEK, 2020). In Kuujjuarapik, this increase will consist of the addition of a fourth 1880 kW generator (CQEK, 2021b, 2022a). However, the 2023-2032 off-grid supply plan shows the power balances for each plant for the period 2022-2032. These show the installed capacity of each plant for each year, taking into account capacity increases (HQD, 2022). These values have been used to complete the information required to complete Tableau 3.7 and Tableau 3.8.

Tableau 3.7 Scheduled power increases in Nunavik
Compiled from CQEK (2020, 2021b, 2022a) and HQD (2022)

Village supplied	Expected period of power upgrade	Installed capacity after upgrade (kW)
Salluit	2023	4768 à 5168
Kuujjuarapik	2024-2025	5285
Quaqtaq	2024-2025	2270[(1)]
Kuujjuaq	2026-2027	7890[(1)]
Kangirsuk	2028-2029	2270[(1)]
Kangiqsualujjuaq	2030-2031	3160[(1)]
Umiujaq	2031-2032	2270[(1)]
(1) These power balance values do not distinguish between an increase in power and the addition of mobile generators. However, they are unlikely to include the power of mobile generators, as there is - a priori - no reason why a recently upgraded power plant should be assisted by a mobile generator.		

HQ's goal is to “supply 80% of Nunavik's autonomous grids with clean energy by 2030” (HQD, 2022). However, if current statements on generating capacity to 2030 are followed, a profile of Nunavik's autonomous grids emerges for the coming decade. Thus, Tableau 3.8 summarizes all the elements discussed in 3.4.2 and - notably in Tableau 3.6 and Tableau 3.7 - concerning current and future production capacities. Based on the transformations planned or underway, it therefore describes the production capacities of Nunavik's autonomous grids up to 2030.

Tableau 3.8 Potential profile of Nunavik's off-grid generation capacity to 2030

Village supplied	Installed capacity (kW)	Thermal power plant capacity (kW)	Renewable power capacity[4] (kW)
Akulivik	2019	2019	0
Aupaluk[1]	1975	1975	0
Inukjuak	13 500	6000	7500[5]
Ivujivik	1480	1480	0
Kangiqsualujjuaq	3160	3160	0
Kangiqsujuaq[1]	3158 à 6940	3158 à 4600	2340
Kangirsuk	2270	2270	0
Kuujjuaq	7960	7890	70
W-K[1] [2]	8290	5285	3005
Puvirnituq	6500 à 15 300	6500 à 9300	6000[5]
Quaqtaq[1]	2314	2270	44[5]
Salluit[1]	4768 à 5168	4768 à 5168	0
Tasiujaq[1]	1760	1725	35
Umiujaq	2270	2270	0
Total capacity	61 419 à 74 406	50 770 à 55 412	18 924
Share of capacity	100 %	68.23 % à 82.66 %	25.43 % à 30.81 %

(1) For the moment, it appears that there are no plans to modify or transform these grids.
(2) The data used are those described in 3.4.1 and 3.4.2.
(3) Data are extrapolated from (HQD, 2022).
(4) These include hydroelectricity, wind power and photovoltaics.
(5) Battery storage is not counted for any grid.

3.5.2 Power generation for Nunavik's mining sector

Canada has the third largest number of mining industry. Minerals and metals accounted for 3.4% of Canada's GDP in 2020 (historically between 2.7% and 4.5%). In the same year, the mining industry directly contributed $67.5 billion to real GDP, making it one of Canada's major industries. It is also the number one private-sector employer of indigenous Canadians, and the number one business partner for Indigenous companies in the North. The value of mining activities is highest in Quebec. The province boasts the largest number of metal mines (24 out of 70 in Canada) and the largest number of mineral processing facilities. The Nord-du-Québec region accounts for more than a quarter (26.5%) of the province's mineral shipments ($3.153

million), ahead of the Côte-Nord (25.4%) and Abitibi-Témiscamingue (23.3%) regions (Association minière du Canada (AMC), 2022).

At least two companies are active in Nunavik: Glencore Canada Corporation (Glencore) and Canadian Royalties, operators of the Raglan and Nunavik Nickel mines, respectively (AMC, 2022; Énergies and ressources naturelles Québec, 2022; Gouvernement du Québec, 2015). Other mining projects have been described for some years now (AMC, 2022; Énergies et ressources naturelles Québec, 2022), but Raglan and Nunavik Nickel are apparently the only active mining complexes (Madore, 2021). Because these - like the Inuit and Cree villages of Nunavik - are remote from Quebec's main grid, they rely heavily on diesel for power and heat generation, as well as for all their energy needs.

Raglan

Raglan is a base metal-mine: nickel, copper, platinum, cobalt, gold and silver (Canada, 2016). It covers seven sites supplied with electricity. Of these, five are interconnected by a 25kV distribution grid. The other three, including the port and airport, generate their own electricity independently of the rest of the complex, accounting for 11.3% of electricity generation[16]. The 25kV grid alone has an installed capacity of around 50 MW, of which Katinniq, the main site, is the largest contributor with an installed capacity of almost 33.7 MW. The annual electricity production of this grid would be 157 GWh, but the complete complex would produce up to 177.4 GWh yearly (Azin, 2022; Robert, 2023; Tardy, 2022). In addition, at least 15 MW of power would be installed on the Katinniq site to meet heating needs (Comtois and al., 2019). The majority of generating capacity relies on diesel generators, but two wind turbines are now involved (Tableau 3.9). Their case is discussed below.

[16] Apart from this data, no other information is available on their production capacities.

Tableau 3.9 Production capacity and generation of 25 kV grid facilities
Compiled from Azin, (2022), Robert (2023), and Tardy (2022)

Site	Installed capacity (MW)	Average output (MW)	Production (MWh)
Kattiniq	33.645	23.281	123 297
Qakimajurq	3.645	1.752	6318
Mine 2	1.825	1.028	5375
Mine 3	4.675	7.247	4996
Wind turbines(1)	6.200(2)	2.154	17 017
Total	49.990	35.462	157 038
(1) Both turbines are close to the Mine 2 site. (2) Depending on the source, the rated output of a wind turbine is indicated as between 3.0 MW and 3.1 MW.			

In September 2014, a 3 MW wind turbine was commissioned at the Raglan mine site. The project was carried out with Tugliq Energie Co (Tugliq) and supported by the Government of Canada through the ecoENERGY Innovation Initiative. One of the aims of the project was to demonstrate the feasibility of such an installation, and thus set a new standard for wider development in the North. This is the first wind turbine in operation in Nunavik (Canada, 2014; CQEK, 2017; Tugliq, 2016). The success of the project, based on the high energy penetration of the installation and its economic profitability, would be largely due to the storage technologies with which the wind turbine is associated: hydrogen, flywheel and lithium-ion battery (Tableau 3.10). Storage technologies would be a necessity to reach and exceed penetration rates of over 40% (Tugliq, 2016). This first wind turbine, with a charge rate of around 32%, would have reduced diesel consumption by 2.1 to 2.25 million liters per year and GHG emissions by 6,800 tCO_2 eq. per year (CQEK, 2017; Tugliq, 2016, 2019, n. d.).

In 2018, a second wind turbine identical to the first one was installed, along with a 3 MW lithium-ion storage system with a capacity of 1 MWh. This installation is supposed to reduce diesel consumption and GHG emissions in a similar way to its predecessor (Tardy, 2022; Tugliq, 2019b, n. d.-b). In 2021, the storage systems are no longer in use, but the two wind turbines operate with an average load factor of 32.4% and produce 10.8% of the electricity sent to the 25kV grid (Tardy, 2022). However, it is suggested that the mine's electricity consumption increases in proportion to the increase in ore processing capacity. Thus, such an increase unaccompanied by a diversification of power generation methods - following the example of the two wind turbines - would contribute to an increase in the mine's diesel consumption (CQEK, 2017). Finally, a photovoltaic installation was also operated in 2020: a capacity of 40 kWp will be provided by a hundred solar panels (Glencore Canada, 2021). However, this technology is not further developed in the available documentation.

Tableau 3.10 Power and storage capacity report for the Raglan facilities
Compiled from Tardy (2022) and Tugliq (2016, 2019a, n. d.-a)

	Hydrogen system(1)	Flywheel	Lithium-ion battery
Power supply (kW)	198 - 200(2)	200	200
Storage (kWh)	1 000(3)	1,5	250

(1) The hydrogen system consists of an electrolyzer and a fuel cell.
(2) This value indicates the power of the fuel cell. The power of the electrolyzer is 315 kW.
(3) A capacity of 4000 kWh is described by Tugliq (2019a, n.d.-a), but seems inconsistent after cross-referencing sources.

In 2021, the mine would have imported 58.9 million liters of diesel: 43 million liters dedicated to electricity generation and 15.9 million to the operation of machinery and vehicles, heating, and various equipment. GHG emissions associated with these two uses that year were respectively 119,440 tCO_2 eq. and 44,400 tCO_2 eq. for a total of 163,840 tCO_2 eq. (Tardy, 2022). More broadly, the mine's GHG emissions balance, taking into account scopes 1 and 2, represented more than 166,830 tCO_2 eq. considering in particular that the combustion of one liter of diesel emitted 2790 gCO_2 eq. On the other hand, the extent of scope 3 emissions would significantly hinge on air and sea transportation activities involving personnel, equipment, and ore between the mine and other parts of the province. Notably, more than 800 flights occur annually, and the mine receives diesel supplies eight times a year through an ice-breaking ship (Robert, 2023). The mine's current objectives for decarbonization entail reducing diesel consumption by 38 million liters and cutting associated GHG emissions by 105,600 tCO_2 eq. by the timeframe of 2037-2038 (Azin, 2022; Tardy, 2022).

<u>Nunavik Nickel</u>

Nunavik Nickel is also a base metal mine: nickel, copper, platinum and cobalt (Canada, 2016). It is owned by Canadian Royalties, the third largest fossil fuel consumer in the Canadian Arctic and the third largest greenhouse gas emitter in the Arctic, consuming 43.1 million liters of diesel and emitting 106 626 tCO_2 eq. per year. Like the Raglan mine before the installation of its two wind turbines, the Nunavik Nickel mine is 100% dependent on diesel. In 2015, its production capacity was at least 17 MW and it generated at least 18 GWh of electricity. Today, it produces 75 GWh of electricity and 27 GWh of thermal energy (CQEK and CRI, 2022). Due to the lack of further documentation on its energy system, no further details are available. However, with the help of developer Tugliq, the mine complex will soon be commissioning a pair of wind turbines identical to those at the Raglan mine.

Two wind turbines, the same model as those in Raglan, are scheduled to start operating at the end of 2023 (CQEK and CRI, 2022). Each turbine has a rated output of approximately 3 MW, and Canadian Royalties foresees that they could generate 8,750 MWh per year, resulting in a total of 17,500 MWh. This would save nearly 4.6 million liters of diesel, assuming an average efficiency of 3.81 kWh/L for diesel generators. Also, it would prevent the emission of 14,000 tCO_2 eq. every year. Tableau 3.11 provides a detailed presentation of these figures, which show slightly higher estimates than the ones reported for the Raglan mine. In addition, the two wind turbines will be connected to a storage battery, although its characteristics remain unknown (CQEK, 2022b, 2022a, 2022d, n. d.). The installation work is scheduled to occur between June and December of 2023 (CQEK, 2023a).

Tableau 3.11 Nunavik Nickel mine fuel consumption and avoided GHG emissions data Taken from CQEK and CRI (2022)

Annual fuel consumption avoided (L)	Avoided annual consumption including transportation(1) (L)	Annual emissions avoided(2) (tCO_2 eq.)	Total avoided emissions(2)(3) (tCO_2 eq.)
4 593 176	5 052 493	14 095	352 385
(1) Transporting fuel to the mine accounts for an additional 10% of consumption (ISO 14 064). (2) The emission factor used is 2789.793 g CO_2 eq. / L. (3) These emissions take into account the entire lifespan of the wind turbines, which is estimated at 25 years.			

Brief conclusion

In short, the main prospect for decarbonizing the electrical energy of Nunavik's mining complexes is the integration of renewable energy via wind turbines adapted to northern environments. To improve the profitability and efficiency of these systems, notably by maximizing their penetration rate, energy storage appears to be an effective tool. In addition, the successful deployment at the Raglan mine should gradually bring down the price of such deployments, following learning curves. Indeed, initial engineering and design costs are now absorbed (Tugliq, 2016). Figure 3.2 summarizes the status of the production systems of each autonomous grid, including those in the mining sector.

3.5.3 Other sectors: buildings and transport

Transition issues are often classified into four or five sectors: energy, industry, buildings, transport, and agriculture[17] (Lamb and al., 2021). The first has been presented at length and the second partially covered in 3.5.2. Agriculture, on the other hand, was dealt with in 3.4.3, in connection with greenhouse cultivation. This leaves buildings and transport, two sectors cited by Boisseau-Bouvier (2019) as taking part in the region's energy landscape.

[17] More generally: agriculture, forestry and land use.

Transport

Unfortunately, the subject of transportation, while presenting the same challenges of dependence on petroleum products and pollution as electricity generation, has not yet been studied from an energy transition perspective. Only one document attempts to take stock from a climate change adaptation perspective (Comtois and al., 2019).

Within Nunavik itself, communities are scattered at considerable distances from one another, with no overland roads to link them. Thus, the main means of transportation to cover these distances is by airplane and, to a lesser extent, by snowmobile or even traditional dog team - a practice that is gradually fading away (Boisseau-Bouvier, 2019; St-Onge, 1996; Verreault, 2015). On the other hand, the only means of transporting goods or people between Nunavik and outside its borders are by boat and plane. However, the cost of transporting goods by sea ($418/ton) is lower than by air ($5650/ton). As a result, each village receives two to four ships a year for goods or energy products, while the mining sites are supplied year-round, particularly with hydrocarbons and other products: petroleum products (diesel, fuel oil, kerosene for aircraft, gasoline for light vehicles), lubricants and other derivatives of petroleum products such as propane or butane, and chemicals (Comtois and al., 2019). The mining sector has contributed to the increase in maritime traffic throughout Nunavik, as it supplies the Raglan and Nunavik Nickel mines (Lasserre and al., 2016).

Maritime transport is also the only way to provide vehicles to communities. In fact, the use of private trucks, as well as recreational and utility vehicles, is on the rise (Comtois and al., 2019). On the other hand, this vehicle could undergo a transition at the same time as grid conversion. Indeed, battery-powered or hydrogen-powered electric vehicles could be used as storage capacity to manage the intermittency of renewable energies and increase their penetration rate (Tugliq, 2016; van der Kam and al., 2018; Zuliani and al., 2021). However, for the time being, economic levers favor the combustion engine. Indeed, the additional costs generated by the transportation of fuels and the management of their stock are partly offset by KRG and Makivik. These institutions subsidize gasoline for the Inuit beneficiaries of the JBNQA. In particular, this assistance facilitates certain traditional hunting and fishing activities (Makivik, 2018, cited in Boisseau-Bouvier, 2019). Most recently, this subsidy was 75¢ per liter, reducing the price of gasoline from $2.685/L to $1.935/L (KRG and Makivik, 2022).

Buildings

In Nunavik, electricity consumption is an economic issue, as its production is costly for the distributor HQD, and even runs at a deficit (see 3.6.1 and 3.6.2 for more details). Consequently, it seeks to control this consumption and promote other energy sources. Thus, buildings mainly consume and use electricity for lighting and other uses, and light fuel oil to heat water and spaces[18] (SHQ, 2018). Thus, the communities would consume more than 28 million liters of fuel oil for water and space heating (Comtois and al., 2019). However, the case of Inukjuak now stands apart. The new hydroelectric plant allows the conversion of space heating systems to dual-energy electricity/oil and water heating systems to electricity for all residential customers in the community. As a result, the area's electricity consumption has begun to increase as systems are converted (HQD, 2022).

A report by ECONOLER and HQD (2019) provides an overview of electricity consumption by end use in the residential and commercial/institutional (CI) sectors. In the first, household appliances are the largest consumption item (46%), followed by ventilation (16%), outdoor appliances (13%), lighting (10%) and heating (5%). The share of heating is very low, as this use of electricity is discouraged in Nunavik (see 3.6.1 and 3.6.2). Figure 3.3 illustrates the different residential uses. The commercial and institutional (CI) sector is further classified into 25 building types. The three biggest consumers are distinctly offices, schools and grocery stores, but each does not distribute its consumption across the same uses (Figure 3.4).

[18] In particular, the heat transfer fluid used for space heating is a mixture of water and glycol.

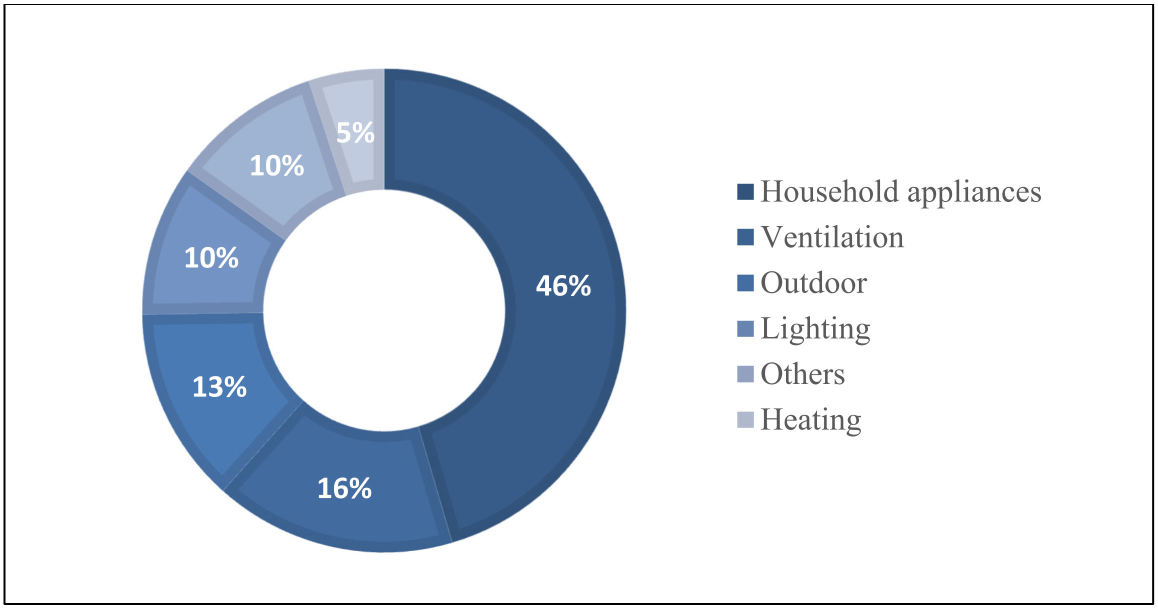

Figure 3.3 Distribution of residential electricity consumption by end use
Adapted from ECONOLER and HQD (2019)

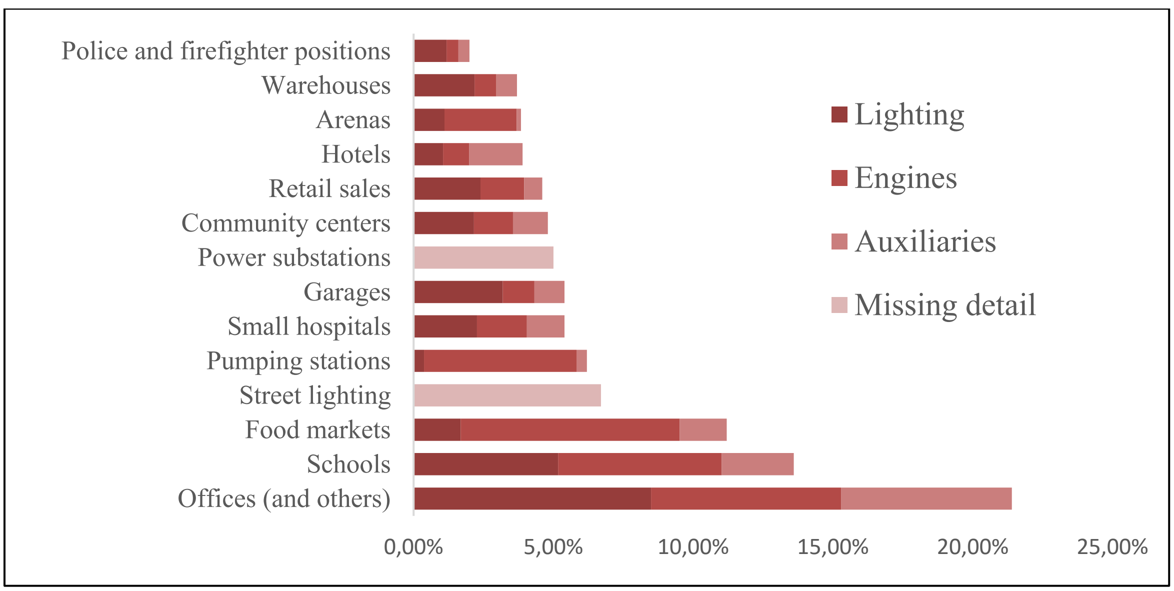

Figure 3.4 Distribution of electricity consumption in the CI sector
by end use for the 14 building types with the highest consumption
Adapted from ECONOLER and HQD (2019)

Similar, but more precise, work is carried out to investigate the causes of consumption exceeding a certain threshold, in this case defined by the second tier of tariff DN (see section 3.6.1). He explains that most heating systems are oil furnaces, and to a lesser extent boilers.

Homes are then analyzed according to this difference, and it emerges that among them, those heated by a furnace are more likely to use electric auxiliary heating. However, these homes do not necessarily consume more electricity: on average, they consume 11 054 kWh per year, whereas homes with boilers consume 11 261 kWh per year. Finally, recommendations are made on the home itself and on efficiency measures to be taken that could reduce energy consumption by several thousand, even tens of thousands of kWh (Legault-Dubois and HQD, 2019).

Brief conclusion

While the existing documentation provides valuable insights into the building sector, it lacks the data necessary to produce a comprehensive balance sheet similar to the one presented in section 3.5.1. Apart from the energy sources and certain contextual factors, there is little information available on the quantity of fuel oil consumed and the resulting GHG emissions. The transportation sector, which is virtually ignored, also lacks data, although it seems possible to collect some (Comtois and al., 2019).

3.6 Energy costs and consumption control

3.6.1 Electricity costs: from generation to customer

Based on petroleum products, electricity generation in Nunavik is expensive compared to the rest of Quebec. In 2010, the average cost of generation was 43¢/kWh in autonomous grids, but was even higher in Nunavik with an average of 75¢/kWh, reaching $1/kWh or more in some villages (Figure 3.5). The cost of this generation is mainly shared between three components: “fuel purchase”, “depreciation and interest”, and “operating expenses”, which represent respectively 35%, 28% and 24% of the total cost. However, this distribution can vary depending on the grid. In Nunavik, fuel can account for up to 65% of costs, depending on current prices. In fact, petroleum product prices have been rising over the past decade (Régie de l’énergie, 2010, 2023), which is why reducing diesel consumption for power generation is a real challenge for HQD. Moreover, the remaining share of costs includes commercial programs designed in part to reduce these charges (HQD, 2011).

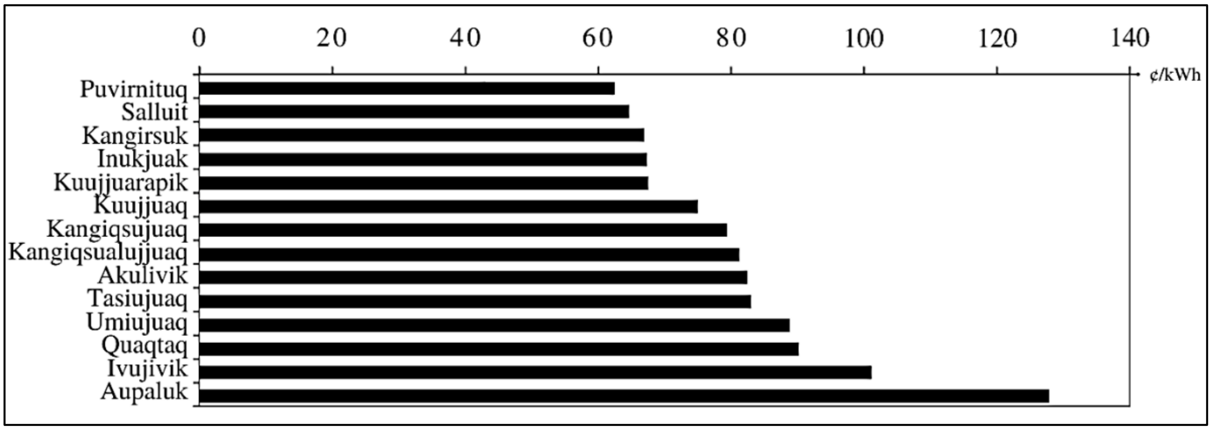

Figure 3.5 Community rankings by average total production cost in 2010 (¢/kWh)
Adapted from HQD (2011)

The issue of cost control also stems from the Régie de l'énergie Act. This law requires that rates applied to autonomous grids be the same as those applied to the integrated grid. The only exception to the exact application of this regime is north of the 53rd parallel, i.e. throughout Nunavik, where consumption is subject to a significant rate constraint above a certain threshold (HQD, 2011). Consumption by residential customers is divided into two tiers: before 40 kWh per day and above 40 kWh per day[19]. In all grids south of the 53rd parallel, including autonomous and integrated grids, tariff D is applied. North of the 53rd parallel, tariff DN is in effect, with the exception of the Inukjuak grid, where it has recently evolved into a dual-energy tariff accessible to customers eligible for tariff DN (Tableau 3.12). Inukjuak's specificity is explained by the upcoming commissioning of Nunavik's first hydroelectric power station (see section 3.4.2).

[19] The previous threshold was 30 kWh. It has been redefined after 2019.

Tableau 3.12 Electricity prices for residential customers by region
Taken from HQ (2022b)

Location	Price per kWh (1st tier) < 40 kWh	Price per kWh (2nd tier) > 40 kWh
South of the 53rd parallel Autonomous and integrated grids (Tariff D)	6.509 ¢/kWh	10.041 ¢/kWh
North of the 53rd parallel[20] Nunavik autonomous grids (Tariff DN)	6.509 ¢/kWh	44.352 ¢/kWh
Special case of Inukjuak (Tariff dual-energy or DNI)	6.509 ¢/kWh	23.990 ¢/kWh
These rates are updated annually and come into effect on April 1 of each year. Added to these rates is a daily grid access charge of 43.505¢ per day in 2023.		

The price of the second tier is four to five times higher in Nunavik than in the rest of Quebec. Yet even this price does not offset operating costs. HQ is therefore running a permanent deficit on electricity production in Nunavik. However, the company is seeking to reduce this deficit by focusing on a number of areas, including “conversion of autonomous grids” and “energy efficiency measures”. One of these interventions is applied exclusively in Nunavik: “dissuasive pricing”. This explains the price differential between Nunavik and other grids for the second tier. HQD encourages customers north of the 53rd parallel to limit their electricity consumption and restrict them to certain uses. The only exception to this will be the village of Inukjuak. The construction of the village's hydroelectric power station promises sufficient, low-cost production to enable “the conversion of all residential customers in Inukjuak to electric heating” (HQD, 2019a, 2022).

Other adjusted tariffs exist for structures requiring small or medium powers greater than those offered by tariff DN, such as municipal, government or business infrastructures, which HQ calls “business” customers (HQ, 2022). These are rates G, G9, M or MA. They are applied

[20] With the exception of the Schefferville network, which is subject to the same rates as the southern grids.

according to power demand and energy consumed. For example, tariff M is applied for medium power, below 900 kW and 390 MWh per month, and tariff MA is used to bill consumption above this level (Tableau 3.13). In all cases, it is explicitly stated that electricity subject to these four tariff types "must not be used for space or water heating, or for any other thermal application", with the exception of "the supply of heating cables in water supply pipes to treatment plants" and for "the manufacture and preservation of ice in arenas". In addition, these loads must be interrupted if Hydro-Québec deems it necessary to manage peak demand (HQ, 2022b).

Tableau 3.13 Electricity prices for business customers
Taken from HQ (2022b)

Tariff	Billed power	Billed consumption
Tariff M	16.139 $/kW	5.567 ¢/kWh (< 210 MWh) 4.128 ¢/kWh (> 210 MWh)
Tariff MA Production based on heavy diesel	37.767 $/kW	28.762 ¢/kWh
Tariff MA Other types of production	68.306 $/kW	70.904 ¢/kWh

<u>Brief conclusion</u>

All in all, electricity production and sales costs are relatively high in Nunavik. They reflect both the territory's energy constraints and the means put in place to control consumption. In addition, they highlight the interdependence of this energy carrier with petroleum products: although they enable electricity to be produced, their cost is a constraint, but it is still cheaper to use them for uses that electricity would provide at higher cost, notably thermal uses. These thermal uses are explained further in section 3.6.2. Finally, Mercier (2022) calls into question the billing system applied, proposing a new model that redefines both prices and the place of energy in the community as an object of common good. This fairer model would also enable energy savings.

3.6.2 Consumption constraints and energy efficiency measures

To optimize the gross amount of energy expended - and the associated costs - for the needs of Nunavik communities, electric space and water heating is largely discouraged, if not prohibited, in favor of other energy sources such as petroleum products (fuel oil). This is one of the roles of dissuasive pricing: to encourage customers to use heating oil rather than electricity. This is cheaper for the distributor HQ, whose electricity production in autonomous grids is already in deficit. It's also cheaper for residential customers, who limit their consumption to the first tariff tier. Indeed, basic needs (lighting, household appliances, etc.) can be covered by the first tier, since customers' average electricity consumption would be between 15 and 22 kWh per day[21] (HQ, n. d.). However, the dissuasive quality of the tariff is called into question. Indeed, it is likely that the "price signal" is not working. The majority of residents are tenants, and as electricity is included in the rent, the management of the electricity subscription is the responsibility of the landlord. Residents therefore never see a bill (De Tilly, 2019). In concrete terms, over 80% of tariff DN customers are affiliated with one of the following institutions: KRG, Makivik, Kativik School Corporation, and especially the Kativik Municipal Housing Bureau. In total, nearly 95% of residents live in housing managed by an organization (HQD, 2019b).

Other incentives go hand in hand with disincentive pricing, and in particular the “programme d'utilisation efficace de l'énergie” (PUEÉ) (HQD, 2019). It first appeared in 2011, as another economic incentive to use oil - or a combination of oil and wood - as the main source of space and water heating. Specifically, residential customers who sign up to PUEÉ see their heating costs reduced by around 30% compared to what it would cost them to heat with electricity, fuel price fluctuations included (HQD, 2010, 2011; HQ, n. d.). In fact, HQ covers 30% of fuel costs for both residential and business customers, as well as annual maintenance and repairs (HQD,

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[21] Interval consistent with the value calculated in 1.7 by dividing total annual sales by the number of inhabitants, but it is not explained whether this interval corresponds to household or individual consumption.

2010b). In 2022, this contribution was 50.77¢ per liter of fuel oil for residential customers, and 53.58¢ per liter for business customers (HQD, 2022).

There are also other incentives to use heating oil or to use electricity. For example, if a customer requests additional electrical power to install space or water heating appliances, he or she must pay a "special self-supply connection fee". This fee is $5000 for the first 20 kilowatts and $250 for each additional kilowatt[22] (HQ, 2021a, n. d.). On the other hand, CI sector buildings that use electricity as a source of space or water heating pay a penalty on the electricity rate. The price of electricity then returned to 78¢/kWh in 2019 (ECONOLER and HQD, 2019).

In line with the PUEÉ, HQD is seeking to assess the technical-economic potential for energy efficiency or "potentiel technico-économique en efficacité énergétique" (PTÉ) of buildings in the residential, commercial, industrial and institutional sectors. To do this, the distributor analyzes consumption, identifies suitable efficiency measures, assesses their economic potential, and includes them in energy efficiency intervention programs. Over the 2018-2022 period, the PTÉ has been evaluated at 18,701 MWh, representing a 19.7% reduction in consumption and potential savings of around 14,500 tons of CO_2 eq. per year. Of the efficiency measures selected, five accounted for the bulk of the PTÉ, or 14 312 MWh of potential: LED lighting for the residential and commercial sectors, awareness-raising for residential and commercial consumers, and optimization of commercial ventilation systems (ECONOLER and HQD, 2019).

More specifically, energy efficiency interventions fall into three categories for residential customers: awareness-raising, consumption optimization, and energy renovation. Firstly, awareness-raising campaigns on energy efficiency and winter peak demand are carried out,

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[22] This surcharge no longer applies to the Inukjuak grid, which has switched to the dual-energy tariff.

along with the distribution of educational kits and a collective competition. In addition, the deployment of more efficient lighting technologies has been implemented: CFL (compact fluorescent lamp) lighting for indoors and LED (light-emitting diode) lighting for outdoors, and timers for engine heaters (pilot project completed). A pilot project for more efficient washers and dryers has also been completed. Finally, thermal renovation programs (doors and windows) are available. In the commercial and institutional market, efficiency programs for interior lighting and street lighting have been completed and energy audits are underway (HQD, 2019a, 2022). Thus, 8 GWh of energy savings would have been achieved between 2005 and 2021 (HQD, 2021a). In addition, the deployment of LED lighting would be particularly effective, now generating energy savings equivalent to 9% of Nunavik's total annual consumption (HQ, 2020).

Brief conclusion

The production and purchase of energy entail costs that some stakeholders are seeking to reduce. To this end, mechanisms are in place to discourage the use of electricity for water and space heating. While incentives for the CI sector are strict, their effectiveness varies in the residential sector because costs do not directly impact residents. However, heating seems to be based almost exclusively on the direct use of fuel oil. On the other hand, energy efficiency programs are being developed to reduce consumption. Within these programs, replacing lighting with more efficient technologies and raising public awareness are the most advanced actions. Finally, the development of less expensive and cleaner energy sources seems to be the most desirable way forward. This is what the community of Inukjuak has done, for example, and will soon be able to heat its homes partially with electricity.

3.7 Conclusion

In Nunavik, access to energy, particularly electricity, is affected by several factors: production and supply costs, geographical isolation, climate constraints, and population growth, among others. Specifically, the costs associated with electricity production lead Hydro-Québec to adopt a demand management strategy and plan for production capacity evolution. This is especially true since the company now has to pay CO_2 emissions fees for the operation of thermal power plants. Consequently, initiatives to convert Nunavik's autonomous electricity production grids have been proposed for decades, but very few have been realized. In fact, none of the projects envisioned by Hydro-Québec since the late 1980s has come to fruition. Nonetheless, a few communities and businesses have managed to implement projects that have succeeded or are well on their way to succeeding. For instance, the wind turbines at the Raglan mine and the hydroelectric project in Inukjuak have respectively replaced 6.0 MW and 7.5 MW of fossil fuel production with renewable sources. Furthermore, the neighboring communities of Whapmagoostui and Kuujjuarapik, as well as the Nunavik Nickel mine, are expected to soon have wind turbines installed on their premises, also contributing to electricity production.

However, only one other significant conversion project appears to be planned, in Puvirnituq. Moreover, the growing demand, both in communities and in the mining sector, threatens to limit the economic and environmental benefits of renewable production infrastructure. If this growth is not accompanied by an equally rapid development of renewable energy sources, and if the additional demand is met by fossil fuels, the economic and environmental gains could stagnate or even be nullified. It is worth noting, however, that the case of the Inukjuak hydroelectric project, with a comfortable margin of power relative to demand, holds promising prospects in addressing this issue. In summary, achieving Hydro-Quebec's objective of converting autonomous grids by 2030 appears uncertain.

Furthermore, the majority of other energy uses seem to rely on petroleum products, although no quantitative energy balance can be clearly established. Heating spaces and water are almost exclusively provided by oil, and the quantity consumed by the residential sector or the CI sector is not specified. However, the development of heat pumps and especially geothermal energy holds interesting potential. Pilot projects and concrete assessments are currently underway in Kuujjuaq. As for transportation, no report or study has compiled an energy consumption balance for the sector. Yet, the Nunavik region is particularly reliant on aviation for both goods and passenger transport, as well as motorized land vehicles. Lastly, non-electric and non-heating energy consumption in the CI sector is not detailed anywhere. Thus, it is difficult to ascertain whether other uses are made with petroleum products or other sources of energy.

In conclusion, obtaining a clear understanding of the energy system in northern Quebec remains challenging due to a lack of data, particularly regarding non-electric energy supply or consumption. Hydro-Québec's supply plans provide valuable insights into electricity production, although greater data transparency concerning greenhouse gas emissions would be beneficial. However, there is a statistical gap to be filled when it comes to other sources and energy vectors. A more comprehensive statistical coverage would facilitate the monitoring of the energy transition, envisioning trajectories, and setting decarbonization goals – crucial actions to inform societal debates (Grunwald, 2011). Thus, the establishment of a set of transition monitoring indicators would help identify data gaps and drive the creation of data collection policies. To achieve this, the literature suggests various methodological frameworks, guidelines, and structuring proposals (Adelle and Pallemaerts, 2009; Farsari and Prastacos, 2002; Gunnarsdóttir and al., 2020; Vera and Langlois, 2007), and certain international institutions provide recommendations for energy statistics construction (Eurostat, 2020; Garcia and al., 2017; IEA, 2014, 2020; ODYSSEE-MURE, 2020; OECD and al., 2004).

Moreover, Quebec has established a target of reducing greenhouse gas emissions by approximately 37.5% by 2030 at the provincial level (Dunsky, 2021; Québec, 2023). Currently, it appears that the necessary strategies for achieving such a reduction in greenhouse gas emissions at the scale of Nunavik are not yet fully activated, or to a sufficient extent. Indeed, uncertainty exists regarding whether the increasing energy demand can be met by an expanded deployment of renewable energy sources at the current deployment rate. However, this work remains within the bounds of the technical-economic domain and therefore does not offer a comprehensive analysis of obstacles to the transition or existing opportunities. Yet, it is within the realm of multidisciplinary approaches, particularly in the fields of social and human sciences, that more comprehensive answers can be provided. Thus, aspects of governance and participation (Harbour-Marsan, 2018; Harbour-Marsan and Lasserre, 2021; Karanasios, 2018; Paquet and al., 2021; Rodon and al., 2021), socio-economic and political context (Makivik and al., 2014; Merrien, 2021; Méthot, 2019; Stefanelli and al., 2019), and even matters of perception and social acceptability (Fortin, 2020; Weis and al., 2008) offer essential insights into understanding the complexity of Nunavik's energy system.

CHAPITRE 4

BUILDING A SET OF ENERGY TRANSITION INDICATORS AS IT IS PERCEIVED: EXPLORING A PRESS DISCOURSE BASED APPROACH ON NUNAVIK CASE STUDY

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4.1 Abstract

The literature offers various approaches for assessing or monitoring progress towards sustainability goals. Indicator sets, in particular, have the potential to capture the multidimensionality of energy transition processes. Despite their growth over three decades since the publication of Agenda 21, these sets still exhibit several structural shortcomings today. Additionally, the majority are tailored to national scales, with very few focusing on local levels. However, considering local specificities holds multiple benefits and is crucial for certain regions. This article aims to test a new approach that seeks to construct a thematic framework to facilitate indicator selection through press discourse analysis. It is coupled with an innovative methodology to evaluate interactions between these themes. The approach is applied to Nunavik, a northern region in Quebec predominantly inhabited by Indigenous communities. The result is a thematic framework based on eight themes covering socio-economic, energy, political, cultural, environmental, and civil aviation issues. The assessment of interactions highlights significant interweaving between socio-economic issues and access to clean energy, particularly at the residential level. In the end, a set of 28 indicators is selected for the two most technical themes. This method effectively addresses the identified gaps in the

literature. However, methodological adjustments to simplify or enhance robustness are proposed for future applications.

Keywords: energy transition, indicator, discourse study, Nunavik, indigenous, IRaMuTeQ

4.2 Introduction

4.2.1 Research background

Many approaches exist for assessing or modelling the achievement of sustainability objectives, particularly in relation to energy (Ness and al., 2007; Singh and al., 2012). One of these approaches is the sets of indicators, which gained popularity following the publication of Agenda 21 (UNCED, 1992). These tools make it possible to simplify a complex reality by providing information about the issue they address (European Environment Agency (EEA), 1999; Waas and al., 2014). Furthermore, they are likely to take into account the multidimensionality of the issues associated with sustainability (Ness and al., 2007). To do this, however, they need to incorporate environmental and socio-cultural indicators in addition to the traditional technical-economic indicators (Farsari and Prastacos, 2002). In recent decades, the field of study dedicated to the development of indicator sets has been active (Doukas and al., 2012; Gunnarsdóttir and al., 2020; Singh and al., 2012). However, the existing sets have at least five shortcomings: definitional ambiguity, unbalanced focus, lack of contextual relevance, lack of stakeholder participation, and methodological opacity (Gunnarsdóttir and al., 2020; Shortall and Davidsdottir, 2017).

Furthermore, existing sets and approaches are primarily focused on national scales, with few dedicated to smaller scales (Gunnarsdóttir and al., 2020; Shortall and Davidsdottir, 2017). Only Neves and Leal's (2010) contribution attempted to address this gap. However, energy transitions are also rooted at regional, and even local, levels (Coenen and al., 2021). At these scales, transitions are influenced by individual, organisational, and institutional actors involved in energy governance (Mattes and al., 2015). Indeed, the multitude of actors and interests involved in transitions leads to the development of technological and governance contexts specific to local spaces (Fuchs and Hinderer, 2014). Moreover, studying the local scale, particularly in isolated regions, allows for the consideration of social factors that can either promote or hinder the development of transition projects (Montedonico and al., 2018). Furthermore, the study of these factors can be effective at the community level (Mundaca and al., 2018). However, the geographical dimension of transitions lacks attention. Thus, approaches that integrate their territorial aspect and internal multidimensional interactions are necessary, encompassing economic, cultural, and environmental values (Huguenin, 2017). In this line, Glück (2018) discusses the situational approach, a relevant level of analysis for addressing this complexity.

Considering recent criticisms and recommendations from the literature (Gunnarsdóttir and al., 2020; Shortall and Davidsdottir, 2017) and the need to study energy issues at local scales (Montedonico and al., 2018; Mundaca and al., 2018), Chaubier and al. (submitted, not published) propose a new approach. It aims to create a set of indicators capable of monitoring and assessing sustainability at the local level, particularly in the context of energy transition. This approach draws heavily from the methodological proposal of Gunnarsdóttir and al. (2021). The latter seeks to construct a thematic framework by involving stakeholders through a series of semi-structured interviews, focus groups, and surveys. An application case in Iceland demonstrates the effectiveness of this method (Gunnarsdottir and al., 2022). However, Chaubier and al. (submitted, not published) identify obstacles to its application: the difficulty of accessing the study area and the ethical constraints associated with such methods. Therefore, while these latter authors rely on a structure and approach similar to that of Gunnarsdóttir and al. (2021), they propose consulting stakeholders and the context using a press discourse analysis. This methodological proposal suggests that it can be applied to the study of local and even community scales, as well as remote regions. In particular, it would be suitable for studying isolated North American regions inhabited by Indigenous communities.

4.2.2 Purpose of the study and research objectives

The primary aim of this study is to test Chaubier and al.'s (submitted, not published) method on a case study. Nunavik was selected as the study area. This remote region, mainly inhabited by Indigenous communities, faces socio-economic and energy challenges linked to its geographical isolation, intertwined with historical, cultural, political, and governance factors (Fabbi and al., 2017; Harbour-Marsan and Lasserre, 2021; Paquet and al., 2021; Rodon and al., 2021; Rodon and Schott, 2014; Southcott, 2015; Wilson, 2017). This context aligns with Sovacool and al.'s (2018) emphasis on the importance of research dedicated to vulnerable populations and the value of generating new information about them. In particular, the region lacks dedicated statistical coverage of sustainability issues and does not communicate any quantitative energy-related objectives. Thus, energy transition planning remains a relatively uncharted territory, even though significant socio-political and cultural issues are at stake (Paquet and al., 2021). This study aims to address a common lack of shared vision among transition stakeholders regarding its form to achieve sustainability (Serran and al., 2019). Additionally, the region is subject to numerous research projects initiated by external actors or researchers, straining local cooperation capacities, especially in studies involving the social environment (Assemblée des Premières Nations du Québec and du Labrador (APNQL), 2014; Atanniuvik, 2022; Makivik Corporation, 2013, 2022). Furthermore, no press discourse analysis has been conducted in the region, despite a burgeoning literature dedicated to the study of the society-energy nexus in the area (Harbour-Marsan and Lasserre, 2021; Paquet and al., 2021; Rodon and al., 2021; Rodon and Schott, 2014).

On one hand, Chaubier and al.'s (submitted, not published)) method is expected to validate six evaluation criteria dedicated to indicator sets, as highlighted by Gunnarsdóttir and al. (2020): (i) transparency of indicator selection, (ii) use of a conceptual framework, (iii) representativeness of multidimensionality, (iv) consideration of linkages, (v) stakeholder engagement, (vi) transparency of indicator application. It was, therefore, logical to verify this. On the other hand, this test also aims to shed light on other advantages or limitations of the approach, related to its application effectiveness. As a test, the methodology has not been fully applied, with a partial application being sufficient to critique the approach. Specifically, the list of resulting indicators has not been finalised. It will be argued in section 4.6.2 that this step would require more resources. Finally, this application case also seeks to produce an analysis of a socio-technical environment, identifying themes associated with energy transition and their interrelationships in the study area. Moreover, the few selected indicators can serve as a foundation for future research.

This article is structured as follows. Section 4.3 provides the contextual elements essential to understanding the study and applying the methodology. The latter requires a knowledge of the context, in particular to facilitate certain interpretations. This section also provides an overview of the field of research relevant to this study. Section 4.4 then details the methodology and its adaptation to the case study. The results of the steps leading to the development of the set of indicators are then described in section 4.5. Finally, section 4.6 discusses the approach and its prospects for use, before concluding the article.

4.3 Background: Nunavik, overview and regional issues

4.3.1 Portrait of Nunavik

Nunavik is a northern region of Quebec that extends beyond the 55th parallel over an area of more than 500,000 km² (Ministère des affaires municipales and de l'habitation (MAMH), 2022). It is home to 15 Indigenous communities, including fourteen Inuit territories and one Cree territory, with a population of 14,673 and 1,102 respectively (MAMH, 2023). In 1975, Nunavik underwent major transformations with the signing of the James Bay and Northern Quebec Agreement (JBNQA). This treaty led the Inuit and Crees to cede their ancestral rights to the territory of Quebec in exchange for new rights, and led to the creation of several institutions (Grand Council of the Crees and al., 1975). These new actors, along with a transformation of the region's financing, brought about profound socio-economic changes. Nevertheless, Nunavik still faces persistent challenges in this area (Rodon and Schott, 2014) as well as a political and economic quest for autonomy and preservation of its cultural identity (Harbour-Marsan, 2018; Rodon, 2014).

On the one hand, the socio-economic context of Nunavik differs from the rest of Quebec in terms of demographic problems and inequality (Duhaime, 2004, 2007; Duhaime and al., 2021). In particular, the territory suffers from inequalities in income, access to employment, level of education, and access to health and housing (Duhaime and al., 2021; Imani and al., 2021; Poulin and al., 2022; P. Robert, 2021; Robichaud and Duhaime, 2015). On the other hand, the economy is based on few sectors, with mining, construction and public administration accounting for nearly 85% of GDP (Robichaud and Duhaime, 2015). The main sources of employment also include certain public services (KRG, 2011; ISQ, 2020; Lévesque and Duhaime, 2021; Robichaud and Duhaime, 2015). Tourism is also growing in Nunavik, supported by the appeal of natural areas and traditional practices, two cultural pillars for the communities (Antomarchi, 2010; Duhaime and al., 2021; T. Martin, 2012; Robbe and Robbe, 2022). The latter are part of the communities' identity, and they aim to preserve them by striking a balance between tradition and modernity (Antomarchi, 2010; J.-F. Létourneau, 2005). However, the current oil-dependent energy system has many direct and indirect consequences for the environment, undermining these two pillars, as well as the health of local residents (Allard and al., 2012; Bari and Kindzierski, 2018; Caron-Beaudoin and al., 2021; Ford and al., 2012; Furgal and al., 2002; Johnsen and al., 2021; D. Martin and al., 2007; Masyagina and al., 2023; Poulin and al., 2022; P. Robert, 2021; Sherwood and Cassidy, 2014; Taillard and al., 2022).

4.3.2 Nunavik’s energy system

Quebec's electricity distribution grid does not extend all the way to Nunavik. As a result, each of the region's communities is supplied by an autonomous production grid. Nunavik has fourteen such systems, with a total installed capacity of 35 MW, supplied almost exclusively by diesel combustion (HQD, 2022; HQ, 2023). This is partly why the cost of generating electricity is so much higher than the provincial average (Régie de l’énergie, 2010, 2023). Although the Régie de l'énergie imposes a uniform electricity selling price in Quebec, it is four times more expensive in Nunavik above a certain daily consumption threshold (HQD, 2011; HQ, 2022). While this pricing system partially offsets production costs, its main role is to discourage electricity consumption. In particular, the use of electric heating is discouraged or even prohibited for commercial or institutional buildings (Harbour-Marsan, 2018; HQ, 2022, s. d.). In addition, the transport of people and goods is almost exclusively dependent on commercial aviation and cargo ships (Boisseau-Bouvier, 2019; Comtois and al., 2019; St-Onge, 1996; Verreault, 2015. Finally, Nunavik's two mining complexes also depend on autonomous grids and therefore face similar issues to the grids supplying the communities (Azin, 2022; CQEK, 2022; A. Robert, 2023; Tardy, 2022). In short, the region's dependence on petroleum products is almost absolute. Figure 4.1 shows a map of Nunavik's autonomous grids.

However, transition projects are underway. In particular, the intention of the Inuit community of Inukjuak to build a run-of-river hydroelectric power station (HQD, 2011) has come to fruition, and the infrastructure should be operational in 2023 (CQEK, 2019; HQD, 2011, 2022). On the other hand, the Whapmagoostui-Kuujjuarapik grid is also carrying out a project born of a community initiative (Conseil de la première nation de Whapmagoostui, 2012; Morin and al., 2017; Nimschu Iskudow, s. d.). The current project would involve installing two wind turbines of 1.5 MW each (HQD, 2022; KWREC, 2022; PESCA, 2021).. The system could be commissioned in December 2023 (HQD, 2019, 2020, 2021a). These two projects are for the moment the only large-scale projects that are truly advanced. Finally, mining sites are banking on wind power to reduce their dependence on oil (Azin, 2022; CQEK, 2022; Robert, 2023; Tardy, 2022).

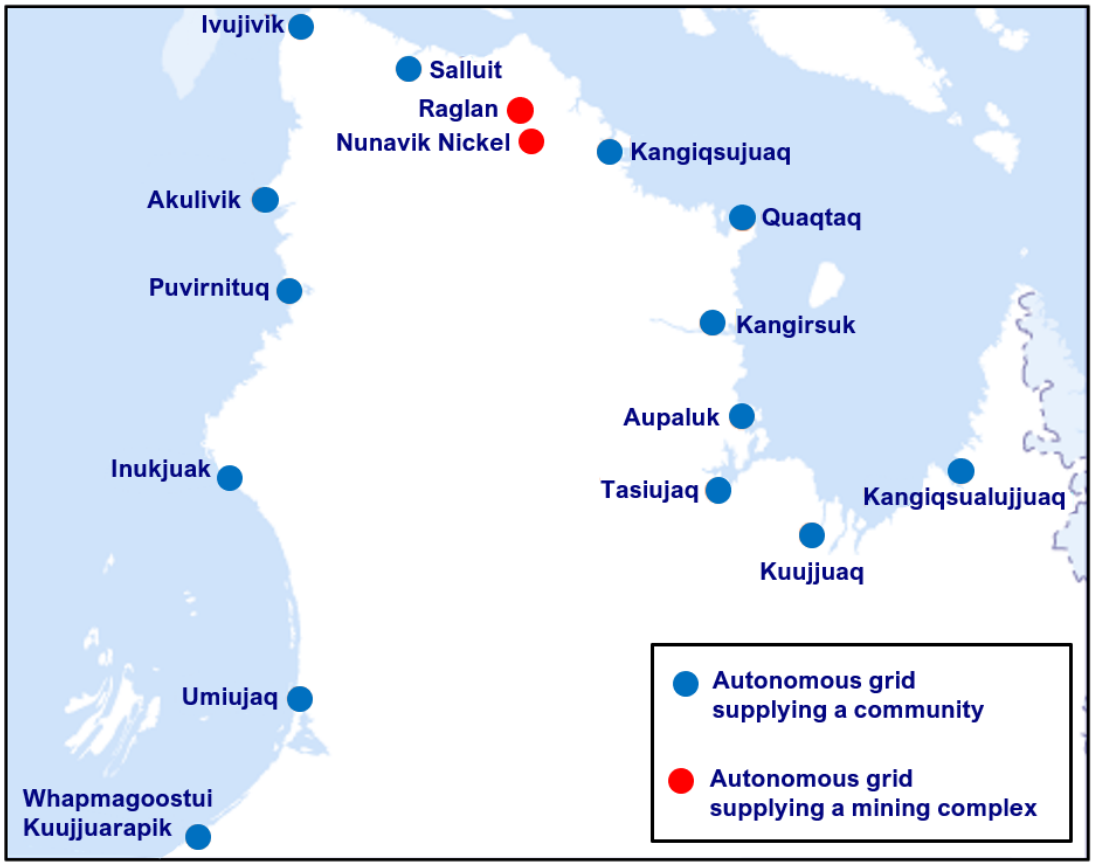


Figure 4.1 Map of the autonomous grids in Nunavik
Adapted from Hydro-Québec (2023)

4.3.3 Stakeholders and discourse study

Some research in Indigenous or Canadian contexts highlight the study of stakeholder perceptions as a means to identify barriers or perspectives on transition. For instance, this approach helped explain the techno-economic constraints to wind-diesel hybrid development in isolated Canadian communities dependent on thermal power plants (Weis and al., 2008). Rather than focusing on techno-economic aspects, these approaches revealed that the acceptance of wind energy in Saskatchewan was contingent on a knowledge and usage habits barrier (Osazuwa-Peters and al., 2020; Richards and al., 2012). In the Indigenous context, a study involving the populations of fifteen Inuit communities in Canada, including four in Nunavik, provided guidelines for the implementation of climate change adaptation policies (Ford and al., 2010). Lastly, a set of "culturally and contextually adaptive indicators of organisational success" for the region was developed based on a series of structured interviews conducted with representatives of Nunavik organisations (Fraser and al., 2022).

However, press discourse analysis is hardly used to study stakeholder perceptions in Quebec (Bertrand, 2019), while the literature shows an increasing number of applications in other territories (Comby and al., 2019; Desvallées and Arnauld de Sartre, 2023; Ganowski and Rowlands, 2020; Hamman and al., 2017; Meyer, 2021). On the other hand, studies of other discourses or at the Canadian level provide contextual elements related to the Indigenous position on environmental and energy issues. Firstly, some reveal a contrast between Indigenous discourses and those of government or private actors. The discourses surrounding energy or industrial projects reveal that despite improvements in participation, negotiations between the Canadian government and Indigenous peoples are biased in favour of the alliance between the state, businesses, and administration (Luig, 2011). Furthermore, there is a contrast between the discourses of the Canadian and Quebec governments and Indigenous communities regarding the environment. It reflects a different perception of the human-environment relationship, implying a lack of understanding of the difficulties faced by Indigenous peoples and underlying tensions (Audet, 2015; Harrington and Lecavalier, 2014; Weigel, 2016). Moreover, past colonial and political relations have an impact on the development of structures related to natural resources in northern Quebec (Desbiens, 2004). Additionally, studies demonstrate the existence of unfavourable representations of Indigenous groups in the media. They disproportionately associate them with Indigenous opposition to hydroelectric dams and omit the historical context of colonialism (Walker and al., 2019). More generally, media coverage of Indigenous environmental issues in Canada and the United States disseminates problematic media representations and highlights the use of force against Indigenous rights (Lowan-Trudeau, 2021). In parallel, the discourse analysis of non-Indigenous energy actors shows that their lack of exposure to Indigenous history affects their commitment to reconciliation (Walker and al., 2021).

4.4 Methods

4.4.1 Global overview of the methodology

The methodology of Chaubier and al. (submitted, not published), inspired by Gunnarsdóttir and al. (2021), was applied with the aim of building a set of indicators suitable for depicting and monitoring the energy transition in Nunavik. The methodology is divided into five steps shown in Figure 4.2. The first step involved conducting a press review to gather material for analysing stakeholder perceptions (1). Specifically, this process entailed the compilation of a corpus of press articles. Subsequently, hierarchical classification analysis (HCA) was employed to construct a thematic framework based on this corpus (2), followed by the identification of interlinkages among the themes that underpin the framework (3). The HCA was led thanks to the IRaMuTeQ software, while interlinkages were identified using a preexisting python algorithm. The selection of indicators was then aligned with the thematic framework (4). This fourth step, as well as the fifth and final step of presenting the set of indicators (5), was only partially implemented. The last step is intended primarily for full applications of the methodology, in order to make the results useful for the general public and for policy making. It is therefore not necessary for the partial test application proposed in this study.

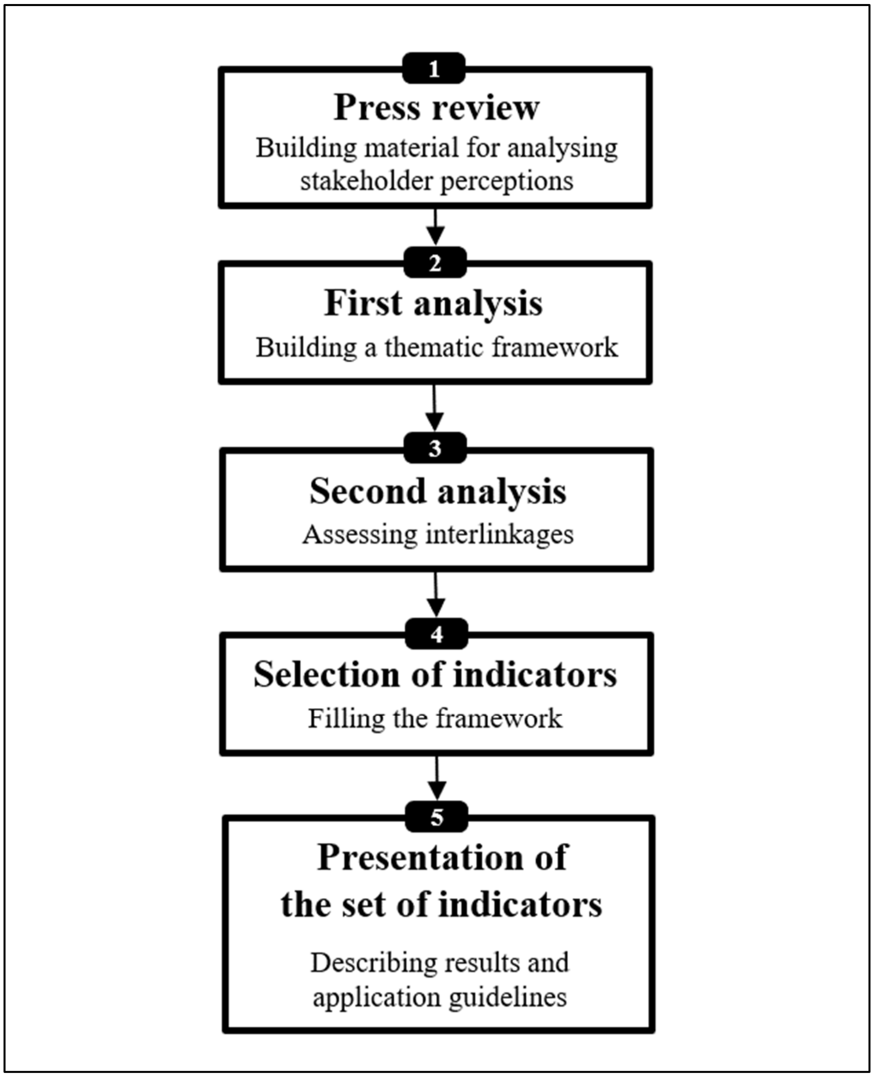


Figure 4.2 Diagram illustrating the main steps of the methodology
Taken from Chaubier and al. (submitted, not published)

4.4.2 Step 1: Conducting a press review

4.4.2.1 Theme and objectives of the press review

A press review was carried out on the subject of energy transition in Nunavik. This transition process, which is sometimes perceived as exclusively technical, is in fact also the result of social, economic and political factors (Cherp and al., 2018; Fortin and al., 2016; Geels and al., 2016). It is a reality that does not escape isolated northern communities (Holdmann and al., 2022; Pinto and Gates, 2022). Thus, the purpose of this review was to highlight and identify these factors and how they interact. This approach allowed to assess the persistence of any type of mediatised information: event, project, image, opinion, news, decision or policy. In other words, it's a way of exploiting the surplus of information that emerges from the press (Chartier, 2003). Thus, the method postulated that the press review enables conjectures to be made directly on the perception of stakeholders.

In concrete terms, this study aimed to identify the themes of the energy transition as perceived by the communities of Nunavik and the local, provincial and federal actors involved in this transition. More broadly, the study also examined the perception of energy in Nunavik. As this energy is not subject to the same constraints and issues of access and distribution as elsewhere in Quebec (Cherniak, 2015; Karanasios and Parker, 2017), its perception differs from that in the south of the province (Paquet, 2022; Paquet and al., 2021). In addition to participating in the construction of the thematic framework, understanding the representation of energy and the services it provides (food supply, transport, heating, lighting, etc.) helped in the interpretation of the results, and eventually in understanding the barriers to the energy transition (Osazuwa-Peters and al., 2020).

Moreover, the existing relationship between energy and the environment, and between Inuit culture and the environment (J.-F. Létourneau, 2005), leads us to deliberately include the environmental dimension in this analysis. Indeed, the interfaces between the environment and ancestral practices are manifold: food, the use and harvesting of natural resources, language, and now economic development (Martin, 2012; Redvers, 2020; Robbe and Robbe, 2022). Also, the consequences of climate change are already having an impact on the northern environment and therefore on Inuit traditions (Hocine, 2018; Stuckenberger, 2010). Energy is closely linked to climate disruption and environmental change (IPCC, 2021; Richardson and al., 2023; Tomislav, 2018), both globally and in Nunavik. The notions of environment and climate are therefore taken into account in the press review via the choice of keywords (see 4.4.2.4).

In short, this analysis must answer the question: What themes are related to energy in Nunavik, and how do they interact? In addition, other questions may guide the study: What themes are associated with environmental degradation and climate change? How do energy and local traditions interact? How are technologies for producing or using energy perceived?

4.4.2.2 Elaboration of the initial corpus

The corpus studied in this press review is based on a combination of regional (Nunavik scale), provincial (Quebec scale) and even national press. Initially, only local or regional magazines were to be selected in order to target local communities and actors more specifically. However, there is apparently no press dedicated to a single Nunavik village or community. The smaller-scale press dedicated to Nunavik starts at regional level, and only two magazines offer articles clearly dedicated to the region. These are *Taqralik Magasine* and *Nunatsiaq News*. Thus, the construction of the corpus was based on the availability of material, and three possibilities were considered to build up a sufficiently extensive corpus. The first possibility is to extend the corpus to a sample of the Quebec (provincial scale) and Canadian (national scale) press, selecting only articles dedicated to Nunavik. This option has the advantage of including more of Nunavik's energy transition actors, whose scope and roots are not specifically coherent with the regional scale. The second option is to include an ethnic interprovincial press that carries the voice of indigenous peoples, such as *Inuktitut Magasine* or *La Voix Des Premières Nations*. This option has the advantage of enriching the analysis of indigenous perception, although there is a risk that it will be over-represented in relation to the other actors in the transition. Finally, the third option is to carry out the first two.

Finally, the first option is preferred mostly for practical reasons. The Quebec press is easily accessible and almost exclusively French-speaking. Conversely, the magazines associated with the second option are more difficult to access and require greater care in their analysis. In particular, they sometimes mix several languages on the same page, which would require considerable sorting and cause difficulties verifying that each article deals with Nunavik. However, this choice is also substantiated by the advantages it offers in integrating different analytical scales, facilitating a more profound understanding of the intricate dynamics among indigenous and non-indigenous stakeholders, including post-colonial relationships (Desbiens, 2004). It should be noted that the selected press is not specialised in any field. In the absence of anything else, it is a non-specialised mainstream press, which in no way affects the relevance of the analysis, as explained by Comby and al. (2011). Indeed, although the press is biased, it represents and relays the ideas and representations of social groups (Grégory and Williams, 1981, cited in Comby and al., 2011).

Finally, the corpus selection period starts in summer 2017 (June 1, 2017) and ends in winter 2022 (December 31, 2022), i.e. an interval of four years and six months. This period is constrained not only by the availability of certain journals, but also by changes in Nunavik's energy landscape. Indeed, this has been changing rapidly in recent years with the arrival of new energy stakeholders on the territory: Les Énergies Tarquti, Innergex (Harbour-Marsan, 2018) or even the Kuujjuaraapik Whapmagoostui Renewable Energy Corporation (KWREC) (KWREC, 2020). This timeframe is relatively short, but sufficient. It allows to study the issue of energy over a wide perimeter, taking into account the diversity of socio-technical interactions (Hamman and al., 2017).

4.4.2.3 Presentation of the analysed newspapers

Regional press

Taqralik Magasine, formerly *Makivik magasine*, has been published since 1974, two to four times a year. It is published by Makivik Corporation, the ethnic organisation responsible for representing and promoting the interests of Nunavik. It features news, stories, photos and other content from Makivik subsidiaries, as well as from individuals and organisations connected with the Inuit of Nunavik (Makivik, 2013, 2020). It should be noted that, Makivik being an Inuit entity, the newspaper may give less, if any, attention to the Nunavik Cree community: Whapmagoostui. A first reading of the sample selected for analysis shows a recurrence of the presentation of Makivik's subsidiaries, in particular its supply and air transport activities: Air Inuit, First Air and Canadian North. *Nunatsiaq News* is a weekly newspaper published since

1973. Its content covers Nunavik, Nunavut and Canada's Arctic region. It is therefore necessary to sort articles to exclude or isolate content concerning territories other than Nunavik. Owned by Nortext Publishing Corp. the newspaper receives support from the Canadian government as a local journalism initiative (Nunatsiaq, s. d.). The articles in these two newspapers are written in English and Inuktitut, the official Inuit language in Nunavik. The English-language version is analysed for the construction of the corpus.

Provincial press

A second selection of articles from the Quebec press is added to the corpus, chosen from the most widely consulted media in Quebec (Centre d'Études sur les Médias, 2022; Immigrant Québec, 2021; Isarta infos, 2015) : *Le Journal de Montréal*, *La Presse*, *Le Devoir*, and *ICI Radio-Canada* (CBC Radio-Canada's French-speaking media).

National press

Finally, two sources were considered to complete the corpus on a national scale: *CBC News* and the *National Post*. However, for practical reasons, only *CBC News* was considered. The latter's search engine is much more powerful than the National Post's, which cannot easily identify suitable articles. *CBC News* is a Canadian public media founded in 1941, with a presence in all regions and provinces of the country. Tableau 4.1 summarises the sources on which the corpus is based.

Tableau 4.1 Summary of sources selected to build the corpus

Name of the journal	Publisher / Owner	Type / Speciality	Geographical reach	Publication frequency
Taqralik Magasine	Société Makivik	Generalist - focused on Nunavik	Local	2 to 4 times a year
Nunatsiaq News	Nortext Publishing Corp.	Generalist - focused on Northern Canada	Regional	Weekly
Le Journal de Montréal	Québecor Corporation	Generalist	Provincial	Daily
La Presse	Independent	Generalist	Provincial	Daily
Le Devoir	Independent	Generalist	Provincial	Daily
ICI Radio-Canada	CBC Radio-Canada (state-owned company)	Generalist	Provincial	Daily
CBC News		Generalist	National	Daily

4.4.2.4 Selection of articles and texts: definition and use of keywords

Keywords were used to identify articles corresponding to the theme of the press review as defined in section 4.4.2.1. To avoid introducing bias in their selection, a relatively broad set of keywords was employed, chosen based on the literature describing the energy system of Nunavik. The selected keywords target specific aspects of the territory while also fitting into the broader context of energy transition. These keywords have been classified into five categories: general concepts, energy sources and carriers, energy production, energy uses and energy system and environment actors (see ANNEXE 4.a).

Subsequently, the list of keywords underwent two refinements to enhance efficiency. The initial analysis involved testing the keywords on a subset of the selected press. A significant contrast in the frequency of appearance for each keyword led to the exclusion of less effective ones. Specifically, keywords appearing less frequently than the median frequency of appearance were omitted, with the exception of keywords in the "energy system and environment actors" category. Subsequently, a correlation analysis was conducted to eliminate keywords that identified the same themes and articles, thereby minimising their number while ensuring the identification of appropriate articles for analysis. The removal of keywords resulting from these two analyses does not impact this study, as they would not have significantly introduced themes likely to emerge in the results. Further explanations are provided in ANNEXE 4.a. Finally, a list of 19 keywords is retained for corpus construction and it appears in expression (4.1) which defines the mechanism used for article search. Depending on the journal from which the articles originate, the tools for using keywords differ. In the best situation, it's possible to use advanced tools like Eureka. It was used for provincial and national press. For the *Taqralik Magasine* and *Nunatsiaq News* newspapers, the search mechanics were applied manually. The decision-support tool proposed by Chaubier and al. (submitted, not published) was used. It takes the shape of several conditions whose combinations (True or False) help guide the analyst's choice. Since articles from the *Taqralik Magasine, Nunatsiaq News*, and *CBC News* newspapers were written in English, they were translated into French.

Nunavik AND (energy* OR sustainable* OR environment* OR climate* OR diesel* OR petrol* OR oil* OR electricity* OR solar* OR photovoltaic* OR hydro* OR greenhouse* OR transport* OR "Hydro-Québec" OR Tugliq OR Tarquti OR "Air Inuit" OR "Canadian North" OR "First Air")

(4.1)

where * means that words with the same root are also searched, the use of " " allows searching for the exact word or group of words, and the keyword "hydro" is used instead of "hydroelectricity" to raise the probability of getting all the words with this common root.

4.4.2.5 Implementation of the corpus: coding and manual processing

Each selected article was assigned several variables suggested by Chaubier and al. (submitted, not published). These variables enabled the analysis of the corpus and the thematic framework according to the newspaper of origin (variable 1), the year of publication (variable 2), the geographical reach (variable 3), and the theme (variable 4). Specifically, an analysis of variable distribution and statistic associations with the thematic framework was conducted to identify potential biases and perspectives for improving corpus construction. The modalities of variable 4, which are defined qualitatively by the analyst during the construction of the corpus, represent the main theme(s) appearing in the texts. Tableau 4.2 describes the framework used to define the modalities and how they should be considered for use in the analyses.

Tableau 4.2 Guidelines for the definition and use of modalities for variable 4

Variable modality	Subject covered by the article
*theme_energy	Energy sources or carriers or means of energy production
*theme_transport	Any means of transport
*theme_aviation	Civil and commercial aviation
*theme_covid	*The text would not have existed without the covid-19 pandemic.*
*theme_climate	Climate change and its impacts
*theme_enviro	Natural environment: ecosystems, landscapes, water, soil, atmosphere, etc
*theme_greenhouse	Cultivation in greenhouses and associated infrastructure
*theme_areas	Protection, exploitation, or degradation of natural areas
*theme_mining	Mining sector, its activities, and projects
*theme_economy	Economic issues: finance, employment, legislation, and development.
*theme_politics	Political figures or political issues.

4.4.3 Steps 2 to 4: Building the framework and the final indicator set

4.4.3.1 Step 2: Parametrisation and use of the hierarchical classification analysis

A first hierarchical classification analysis (HCA) was conducted on the corpus resulting from the press review, leading to the identification of several thematic classes, each relying on a sub-corpus derived from the main one. Subsequently, a series of HCAs was applied to these sub-corpuses to delineate thematic subclasses. The parameterisation of this method was based on the variables described in Tableau 4.3, which were configured precisely as suggested by Chaubier and al. (submitted, not published).

Tableau 4.3 Main variables and parameters for HCA analysis

Variable	Type	Description
NTS	Input variable	Number of text segments in the corpus
N_{class}	Analysis parameter	Number of final classes desired
N_{seg}	Analysis parameter	Minimum number of text segments per final class
N_{f_class}	Output variable	Number of final classes
PTS	Output variable	Share of text segments kept in the final classes

In the first analysis, the better parameterisation was achieved with N_{class} set to 18 and N_{seg} set to its default value, equivalent to 158 text segments in the present case. In the following series of HCAs, these variables underwent exploratory testing before their final configuration. This testing involved varying N_{seg} within the range of [25 ;100] and adjusting the value of N_{class} within the range of [4 ;10]. Ultimately, the value of N_{seg} was set uniformly at 25 for all HCAs, a threshold below which the interpretability of the subclasses becomes uncertain. Consequently, only the value of N_{class} was adjusted on a case-by-case basis to optimise the PTS value and the interpretability of the constructed subclasses. As suggested by Chaubier and al. (submitted, not published), classes are interpreted on the basis of concordancers of the characteristic forms of each class and the characteristic segments of these. Finally, the chosen parameters and resulting variables for the second series for the HCAs are presented in the Tableau 4.4.

Tableau 4.4 Variables and parameters of the second series of HCAs

Class n°	Number of text segments	Number of active forms[1]	N_{class}	N_{seg}	N_{f_class}	PTS (%)
Class 1	443	619	10	25	7	96.84
Class 2	172	243	4	25	3	98.26
Class 3	454	611	8	25	4	91.19
Class 4	343	545	9	25	5	88.05
Class 5	193	289	5	25	3	95.34
Class 6	248	392	5	25	3	92.74
Class 7	306	491	6	25	4	99.35
Class 8	486	724	8	25	4	89.30
(1) Only forms that appear at least three times are taken into account.						

4.4.3.2 Step 3: Assessing interlinkages

Following the construction of the framework's thematic structure, the interlinkages between its themes and subthemes were evaluated. To do this, the algorithm provided by Chaubier and al. (submitted, not published) was used to analyse the first 21 characteristic forms of each class and detect whether one or more of them exist in other classes and to what magnitude. This magnitude is measured by ${\chi^2}_{echo}$ and must be higher than the threshold defined by equation (4.2) for the detected form to be considered a lexical echo. This threshold is calculated according to two parameters: ${\chi^2}_{min}$ and τ. The first is given by the lowest value of χ^2 among the first 21 characteristic forms of the analysed class. The second is set according to the guidelines of Chaubier and al. (submitted, not published). For the analysis of general classes from the first HCA, τ is set to 0.4, while this parameter is set to 1.5 for subclasses from the second series of HCAs.

$$
\begin{gathered}
{\chi^2}_{echo} \geq \tau \cdot {\chi^2}_{min} \\
\text{with } \tau, {\chi^2}_{echo}, {\chi^2}_{min} \in \mathbb{R}_+
\end{gathered}
\tag{4.2}
$$

These echoes are then considered as points of contact between the classes, and their magnitude is used to define the strength of the interlinkages between classes. These interlinkages can involve one or several lexical echoes and their strength is denoted as F, following the definition by Chaubier and al. (submitted, not published). Some of these interlinkages, however, may be based on weak or contextually incongruous echoes. Therefore, the interlinkages under consideration were interpreted using the concordancers of the echoes that compose them in the source and destination classes. However, only two primary classes, related to technical issues, and their subclasses were investigated for this methodological test. Additionally, only the strongest interlinkages were interpreted due to a significantly high number of interlinkages in some subclasses.

4.4.3.3 Step 4: Indicator selection

In order to best identify the limitations of Chaubier and al.'s guidelines, the indicator selection step was intentionally conducted in an exploratory manner, with a degree of naivety. The primary goal was not to construct the optimal final set of indicators but rather to explore what insights could be gleaned from a passive application of the tested method. However, the following procedures have been followed.

Indicators were selected by linking the thematic subclasses and their content (see ANNEXE 4.b) to the bank of indicators provided by Chaubier and al. (submitted, not published). If no indicator from this list was suitable for describing a theme or subject, a literature search was carried out to find one or more. In cases where this approach was not sufficient, an indicator was proposed by the authors. Additionally, the assessment criteria suggested by Gunnarsdóttir and al. (2021) were applied to the extent possible (Tableau 4.5). Given the relatively small amount of energy infrastructure in Nunavik, the "Trends" criterion was less restrictive than on a national scale, as individual monitoring of systems is reasonably more feasible. Also, efficiency indicators have been combined with descriptive indicators on several occasions to avoid the biased image that the former can convey (European Environment Agency, 1999). For example, progress in energy efficiency does not necessarily mean a reduction in energy consumption.

Indicators were selected only for primary classes associated with technical issues for this methodological test. Considering this restriction, identified interlinkages between subclasses were taken into account to select decorrelated indicators but this incomplete approach limited their use. A comprehensive application would make them more useful.

Tableau 4.5 Indicator assessment criteria based on
commonly used criteria for indicator selection
Taken from Gunnarsdóttir and al. (2021)

Criteria	Brief description
Interpretability	Simple, easily interpreted, and applied.
Trends	Sensitive to changes and shows trends over time.
Grounded in research	Theoretically sound and measured based on standardised measurement methods that enable international comparison of indicators.
Data availability and quality	Based on data of good quality that are available or readily collected. Data are regularly collected and reported with a minimal time lag to report current information.
Linkages	The interrelation of indicators should be considered eliminating correlated ones. Indicators should be meaningful on their own as well as together with other indicators of the set.

4.5 Results

4.5.1 Thematic framework

4.5.1.1 Press review

The press review resulted in a corpus of 164 texts which is included in the supplementary files to this article. After processing and lemmatisation by IRaMuTeQ, the corpus was divided into 2,836 text segments and comprises 6,720 forms. Out of these, 6,141 were active forms, and 2,724 of them, which appeared more than three times in the corpus, served as the primary data for analysis.

Analysis of the variables introduced in 4.4.2.5 leads to a few conclusions. Firstly, it appears that local newspapers offer relatively strong media coverage and provincial newspapers relatively weak coverage of the theme under study. Secondly, aviation is one of the predominant themes after energy and the environment, but ahead of climate. Moreover, the aviation theme contrasts with the more general theme of transport, which hardly appears at all. Yet the literature on Nunavik's energy system says little about it, and it is not a theme particularly targeted by the press review, even though two keywords are dedicated to it. The extent of this theme within the corpus therefore raises questions and is discussed at greater length in the section 4.5.1.4. Finally, the distributions of years appearing in the corpus seem to indicate that the subject covered by the press review has been receiving increasing media coverage since 2017. It would be interesting to extend the corpus over the years following 2022 to validate or invalidate the trend. More details and figures are presented in ANNEXE 4.c.

4.5.1.2 Outcomes from the HCA

The first HCA led to the identification of eight primary thematic classes. Out of the 2,836 text segments in the corpus, 93.27% were retained and utilised in their construction (Figure 4.3). These classes vary in size, with classes 1, 3, and 8 being the largest, while classes 2 and 5 are the smallest. Finally, those eight primary classes are decomposed into 3 to 7 subclasses. In all, 33 subclasses were extracted. A comprehensive interpretation of the primary classes is provided in the following section 4.5.1.3, and a concise interpretation of all classes and subclasses is presented in Tableau 4.6.

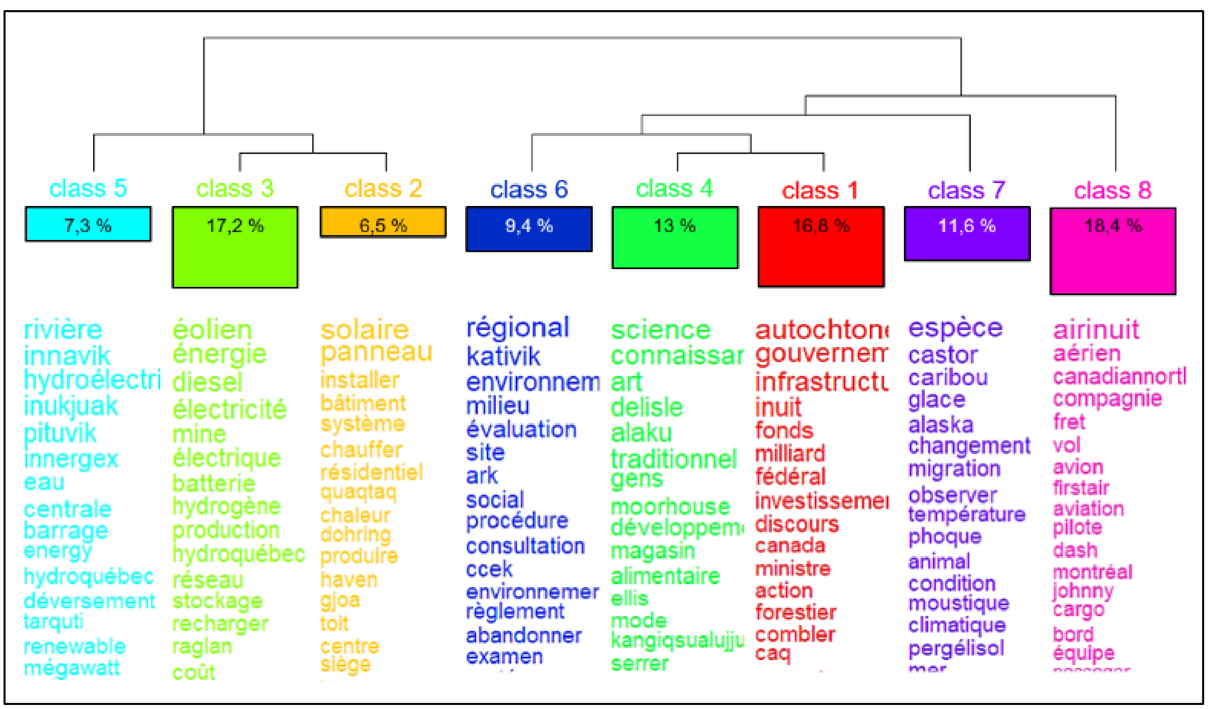


Figure 4.3 Dendrogram of the eight primary classes resulting from the first HCA

4.5.1.3 Analysis and interpretation of the thematic framework

The thematic proximity of the classes is evident in the dendrogram of Figure 4.3. Classes 2, 3, and 5 all revolve around energy-related issues, while classes 1, 4, 6, and 7 address social and environmental concerns. Specifically, classes 1 and 4 delve into social issues, with the latter bridging to environmental aspects by introducing the role of the environment in indigenous lifestyles. Classes 6 and 7 focus more on environmental protection and disruption. Lastly, Class 8 stands relatively isolated, dealing with the aviation sector.

The second class addresses the uses and means of decentralised or small-scale energy production useful for energy transition purposes. More broadly, it mainly focuses on renewable methods of heat and electricity production to reduce dependence on petroleum products and address energy security issues, notably for domestic uses. Specifically, geothermal energy, solar thermal energy, and notably, photovoltaic and wind energy are mentioned.

In contrast to the previous class, the third class deals with centralised means of energy production. It involves thermal power plants around which autonomous grids are built, their associated issues, and their potential for replacement. In particular, it discusses lower greenhouse gas emission technologies that could be implemented in communities and the mining sector. It also covers electricity storage and new uses. The apparent goal is to reduce or eliminate the use of petroleum products for electricity and heat production, as well as for road and industrial vehicles. Specifically, wind energy, and to a lesser extent, solar energy, are considered preferred options. The cost and revenue aspects related to electricity are also addressed.

The fifth class delves into the deployment of alternative energies, particularly hydroelectricity. Furthermore, it highlights the actors in the recent development of these energies in the communities. The focus centers around the only hydroelectric project in Nunavik: the Inukjuak power plant constructed by Innergex. This is associated with the management of groundwater and surface water flows and reservoirs. Moreover, the involvement of multiple actors, community consultation, and their participation in projects emerge as practices in the recent development of alternative energies.

The first class combines various issues related to social development: services, infrastructure, food security, and reconciliation of peoples. These are associated with investment questions, much like certain economic sectors that interact with the environment and energy. These include mining sectors, electricity production, energy supply, and transportation. The latter specifically refers to air transport and the development of electric vehicles. Additionally, the environment and energy are also linked to social development. Finally, Indigenous representation emerges as a governance issue.

The fourth class addresses the lifestyle of northern communities and the challenges it faces in relation to their environment. In particular, the food system suffers from the isolation of the territory, making food supply expensive and of poor quality - similarly to the energy system. Furthermore, it partly depends on traditional foods whose supply is affected by climate change. However, community projects and adaptation appear as key solutions to these issues. Lastly, the interactions between science, culture, and traditional knowledge are highlighted as drivers of progress.

The sixth class deals with the management of environmental and social protection in Nunavik and the actors involved. In particular, it discusses specific environmental issues such as waste management, natural spaces, or mining activities. On the other hand, social and environmental assessment procedures are conducted to regulate project development or decision-making.

The seventh class looks at environmental issues, in particular the impact of climate change and the changes and pressures facing biodiversity. Some species are changing their behaviour or facing new challenges. Yet the food supply and some traditional practices depend on them. These issues also represent a health risk for communities, exposing them to the transmission of viruses. In addition, the northern climate and climate change are putting a strain on the social and health challenges of housing.

The eighth and final class focuses on aviation activities in Nunavik. It highlights its development, particularly the evolution of aircraft fleets to meet demand. Additionally, recent appointments of individuals or executive committees in Nunavik businesses - including airlines - are mentioned. These entities appear to have played a role during the COVID-19 pandemic in negotiating the continuation of aviation activities, which are essential services for the region. Therefore, the region seems to depend on air supply. Finally, the sector is emphasised as a driver of social and socio-economic development, especially for the youth.

Tableau 4.6 Interpretation of primary classes and subclasses

Class n° and title	Subclass n° and title
Class 1 - Sustainable socio-economic development	Subclass 1.1 - Investments in energy and infrastructure
	Subclass 1.2 - Infrastructure and sustainable socio-economic development
	Subclass 1.3 - Levers for reconciliation: cooperation and infrastructure
	Subclass 1.4 - Dependence on petroleum products and transport
	Subclass 1.5 - Mining, forestry and energy industries
	Subclass 1.6 - Fight against climate change
	Subclass 1.7 - Food insecurity
Class 2 - Residential energy and decentralised generation	Subclass 2.1 - Building energy efficiency
	Subclass 2.2 - Heat production and storage
	Subclass 2.3 - Decentralised solar power: photovoltaic and thermal
Class 3 - Centralised power generation	Subclass 3.1 - Power generation and GHG emissions
	Subclass 3.2 - Energy prices and access to energy and other utilities
	Subclass 3.3 - Mining sector: electricity and GHG emissions
	Subclass 3.4 - Energy storage for electricity
Class 4 - Lifestyles facing socio-technical and environmental issues	Subclass 4.1 - Community projects to meet the challenges
	Subclass 4.2 - Science, culture and traditional knowledge: societal levers for development
	Subclass 4.3 - Adapting lifestyles to climate change
	Subclass 4.4 - Nunavik's food system: limitations and prospects

Class n° and title	Subclass n° and title
Class 5 - Alternative energy development and the case of the Inukjuak hydroelectric project	Subclass 5.1 - Inukjuak hydroelectric project development
	Subclass 5.2 - Alternative energy development: stakeholders, governance and community participation
	Subclass 5.3 - Managing water flows and reserves
Class 6 - Concerted protection of the environment	Subclass 6.1 - Extractive activities: exploration, operation and site rehabilitation
	Subclass 6.2 - Waste management
	Subclass 6.3 - Assessment, consultation and protection mechanisms
Class 7 - Climate change and biodiversity: impacts and adaptation	Subclass 7.1 - General impacts of climate change
	Subclass 7.2 - Health impacts related to viruses and mosquitoes
	Subclass 7.3 - Changing behaviour of beavers and other species
	Subclass 7.4 - Disruption of caribou migration
	Subclass 7.5 - Resilience and housing quality in a northern climate
Class 8 - Aviation and airfreight supply	Subclass 8.1 - Adapting and upgrading the aircraft fleet
	Subclass 8.2 - Dependence on airfreight supply
	Subclass 8.3 - Airline Governance
	Subclass 8.4 - Aviation's social role for young people

4.5.1.4 Variable analysis

The analysis of the constructed thematic framework using the variables introduced in the section 4.4.2.5 allowed us to evaluate whether a topic holds a prominent position in the discourse of a newspaper, at a national or provincial scale, in a specific year, or within a particular theme. It also helps us understand to what extent these topics contribute to the formation of a class. Initial insights are derived from Figure 4.4, which provides a purely quantitative overview of the occurrences of each newspaper within each class. National and provincial scales appear to have a significant presence in classes 1 to 3, indicating notable media coverage of social and energy-related issues. However, the coverage of environmental and socio-cultural issues represented by classes 4 to 7 seems to be primarily shared between the two local newspapers. It is noteworthy, though, that class 5, encompassing themes related to energy, the environment, and energy governance, predominantly emerges from the local newspaper Nunatsiaq News. Finally, class 8, dedicated to aviation, is exclusive to the local scale, particularly in the Taqralik Magazine. Further details can be found in ANNEXE 4.c.

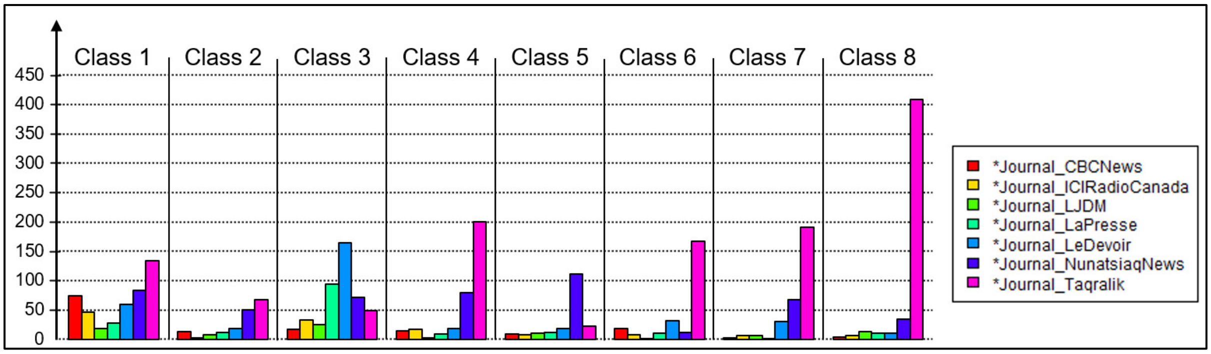


Figure 4.4 Occurrences of each newspaper in each class

Furthermore, Tableau 4.7 summarises the results of the qualitative analysis of statistical associations between variables and classes. It indicates the magnitude of these associations. For the variables *journal, *press, and *year, this can be interpreted based on the level of interest in the thematic class in discourses according to the variable's modality. For the variable *theme, it provides information about the themes associated with the class and potentially its homogeneity. Overall, the observations made based on Figure 4.4 are confirmed but can be nuanced. For instance, socio-economic development (class 1) is only moderately more covered at the national and provincial scales. Conversely, centralised energy production (class 3) is a topic particularly discussed by the provincial press and relatively less so at the local scale. For most other classes, no specific conclusions are drawn, but more explanations are detailed in ANNEXE 4.c. Only class 8 stands out with a very strong association with the Taqralik Magazine and consequently with the local scale. Furthermore, the variable *theme_aviation is extremely strongly linked to this class, while it is negatively related to all other classes, demonstrating its strong thematic coherence. In particular, it shows a strong opposition to the variable *theme_energy, primarily in classes 3, 5, and 8. Thus, the aviation theme represented by class 8 emerges almost exclusively because of Taqralik and highlights its disproportionate place in the discourse from the newspaper, to the detriment of the energy theme. Moreover, this focal object relegates environmental themes carried by classes 6 and 7 to a secondary position in the newspaper's discourse, even though they appear to be topics of major interest to Inuit society (Antomarchi, 2010; Hocine, 2018; J.-F. Létourneau, 2005). This can be explained by the fact that the newspaper is published by Makivik, the owner of Air Inuit and Canadian North, the two airlines that provide air connections to Nunavik and beyond. It appears evident, therefore, that this newspaper introduces a bias in favour of the aviation sector. However, it seems to be isolated from the rest of the thematic framework and, therefore, likely does not influence it. In contrast, the content of class 8 may possibly be subject to a bias rooted in the interests of actors such as Makivik or the airlines.

Tableau 4.7 Interpretation of statistical associations between classes and variables

Class n°	Variables			
	*journal	*press	*year	*theme
1	●● CBCNews ● ICIRadioCanada	●● natio ● local	● 2020, 2021 ● 2022	●● economics ● politics, energy ● aviation
2	No significant association	No significant association	●● 2017 ● 2018, 2021	●● energy ● aviation, enviro
3	●●● LaPresse ●●● LeDevoir ●●● Taqralik	●●●● provi ●●●● local	●●●● 2022 ●●●● 2020	●●● energy ●● mining ● climate ●●aviation
4	No significant association	● local ● provincial	No significant association	●●● greenhouse ● aviation, energy
5	●●● NunatsiaqNews ●● Taqralik	No significant association	●●●● 2019 ● 2017 ●● 2021	●● energy ● aviation, enviro
6	● Taqralik ● NunatsiaqNews	No significant association	● 2017, 2018 ● 2020	●●●● enviro ●● areas ● aviation
7	No significant association	No significant association	● 2019, 2021 ● 2017, 2020	●●● climate ● energy
8	●●●● Taqralik ● LaPresse ● NunatsiaqNews	●●●local ● provi	●●● 2020 ●● 2021	●●●●● aviation ●● covid ●●●● energy
●: slight association, ●●: moderate, ●●●: strong, ●●●●: very strong, ●●●●●: extremely strong ●: slight dissociation, ●●: moderate, ●●●: strong, ●●●●: very strong, ●●●●●: extremely strong				

Only the most useful conclusions are presented here, but the analysis is developed further in ANNEXE 4.c. It can provide additional information on the temporality of the discourse and the distribution of stakeholder perceptions.

4.5.2 Interlinkages

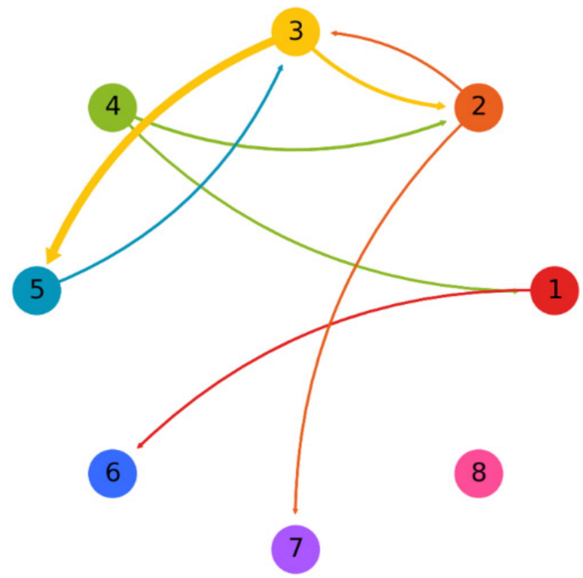
4.5.2.1 Analysis across the eight primary classes

Analysis of the interlinkages between the eight primary classes, parameterised by a τ set at 0.4, leads to the identification of eight links involving classes 1 to 7. Only class 8 is completely isolated, as it is not linked to any other class. Even with τ set at 0.1, this class showed no link with the others. Tableau 4.8 shows the interpretation of each interlinkage based on the echoes concordancers analysis. Those led to the following comprehensive but concise summarise.

On one hand, the sustainability of energy production (class 3) appears to strongly depend on new alternative energy projects, as exemplified by the case of the Inukjuak hydroelectric project (class 5). These projects are also developed with the involvement of various energy actors and stakeholders who exert influence on them. On the other hand, decentralised and residential production methods (class 2) could enable the substitution of fossil fuels (class 3) with renewable energy, particularly through solar power. The residential sector is also a key factor in sustainable energy development in northern regions, addressing issues related to housing quality (class 7). Specifically, energy efficiency and the production of renewable and healthy heat play a crucial role. These technical perspectives also appear to be assets for community greenhouse cultivation, which faces challenges related to sustainable heat supply, alongside other considerations (class 4). Indeed, Nunavik's food system, deeply rooted in its lifestyle, is a factor in socio-economic development and autonomy (class 1). Lastly, this development, associated with changes in the energy system, is influenced by the involvement of various actors, including provincial and federal governments (class 6).

Tableau 4.8 Analysis of the interlinkages between the eight primary classes

Illustration of class interlinkages

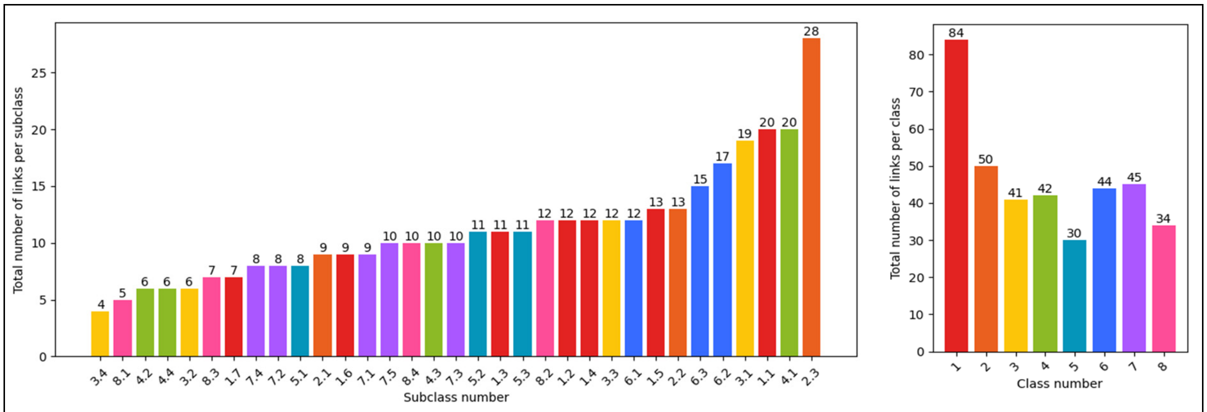


Link	*F*	Interpretation of the binding object
3 to 5	7.48	Conversion of grids to renewable energy sources and the actors involved in this process
3 to 2	2.08	Fossil and renewable energies Electricity generation
4 to 2	1.24	Community greenhouses and other community initiatives
5 to 3	0.90	Inukjuak hydroelectric project Hydro-Québec's involvement in alternative energy projects
4 to 1	0.70	Food systems and food insecurity Socio-economic and community development
1 to 6	0.66	Involvement of the provincial and federal governments in the development of the region and the energy system
2 to 3	0.62	Solar power generation
2 to 7	0.55	Building energy efficiency and building-integrated solar power generation

1. Sustainable socio-economic development, 2. Residential energy and decentralised generation, 3. Centralised power generation, 4. Lifestyles facing socio-technical and environmental issues, 5. Alternative energy development and the case of the Inukjuak hydroelectric project, 6. Concerted protection of the environment, 7. Climate change and biodiversity: impacts and adaptation, 8. Aviation and airfreight supply

4.5.2.2 Analysis across the subclasses

While the interlinkages of the eight primary classes give general indications of the dynamics they reflect, the same analysis dedicated to the thematic subclasses gives more specific insights as they encompass more complexity. Figure 4.5 illustrates the number of interlinkages associated with subclasses, as well as their sum by primary classes. This demonstrates that primary class 1 is the most central in the analysis because its subclasses have the highest number of interlinkages with others. Thus, the socio-economic dimension appears highly intertwined within the thematic framework. However, the distribution of interlinkage among subclasses is more diverse, with subclass 2.3 being dominant. Specifically, the theme of solar energy (subclass 2.3) exhibits interconnections with the majority of other subclasses, followed by community projects (subclass 4.1), investments in energy and infrastructure (subclass 1.1), and centralised electricity generation (subclass 3.1). It could thus be interpreted that these themes are foundational aspects of the energy transition in Nunavik. To address the energy challenges, investments and community participation are essential for the development of sustainable projects and infrastructure. In particular, solar energy is among the technical solutions to be developed.



2.3. Decentralised solar power: photovoltaic and thermal, 4.1. Community projects to meet the challenges, 1.1. Investments in energy and infrastructure, 3.1. Power generation and GHG emissions, 1. Sustainable socio-economic development, 2. Residential energy and decentralised generation, 3. Centralised power generation

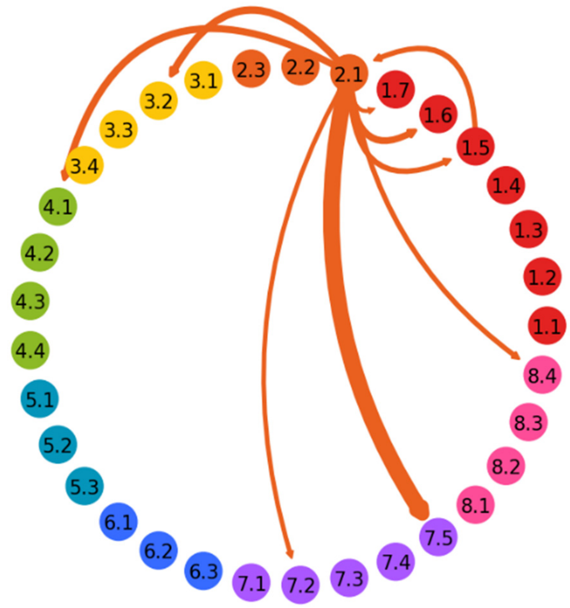
Figure 4.5 Number of links for each primary class and subclass

The interpretation of interlinkages for subclasses 2.1, 2.2, ... 3.3, 3.4 is described in Tableau 4.9 and Tableau 4.10 for the eight strongest in each. Some interlinkages are invalidated and marked with an "X" because they are based on inconsistent echoes. On one hand, some echoes have weak meanings because the related forms have very general scope, such as "Nunavik". On the other hand, some echoes are incongruous because the associated forms are used in very different contexts, like a pilot of an aircraft and a pilot project. Overall, the construction of these interlinkages reveals the practical interweaving of themes within the framework. In particular, Class 2 interacts with issues related to energy access, efficient and resilient housing, and food supply. Class 3 appears to interact more with socio-political issues, including governance and financial aspects of the energy transition, autonomy of communities, and the potential benefits they could derive from this transition. Additionally, sustainable economic development, including mining industries, plays a role alongside efforts to reduce environmental impacts.

Tableau 4.9 Interpretation of interlinkages for subclasses of class 2

Illustration of subclass interlinkages

2.1. Building energy efficiency

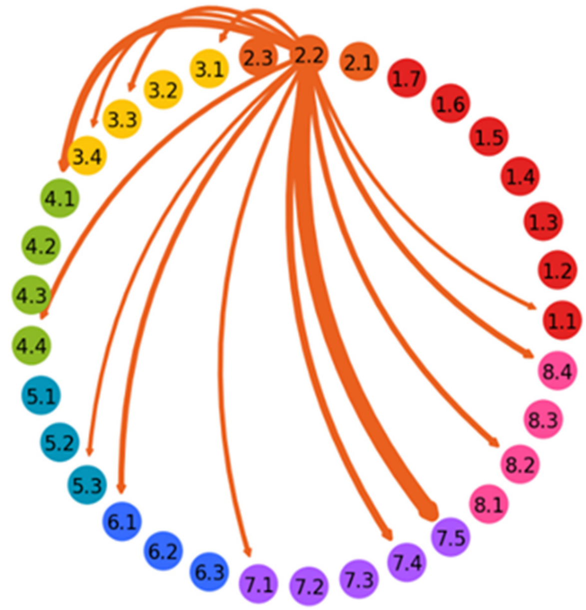


Link	*F*	Interpretation of the binding object
2.1 to 7.5	10.91	Improved design and adaptation of residential units
2.1 to 3.2	3.53	Cost of goods and services and cost of living
2.1 to 4.1	3.40	Socio-economic and energy development programs and plans
2.1 to 1.6	3.13	Energy-related regulatory measures
1.5 to 2.1	2.06	Energy transition and efficiency
2.1 to 1.5	2.03	*Same as link 1.5 to 2.1*
2.1 to 8.4	1.98	X
2.1 to 7.2	1.57	X

7.5. Resilience and housing quality in a northern climate, 3.2. Energy costs and revenues, 4.1. Community projects to meet the challenges, 1.6. Fight against climate change, 1.5. Mining, forestry and energy industries, 8.4. Aviation's social role for young people, 7.2. Health impacts related to viruses and mosquitoes

Illustration of subclass interlinkages

2.2. Heat production and storage

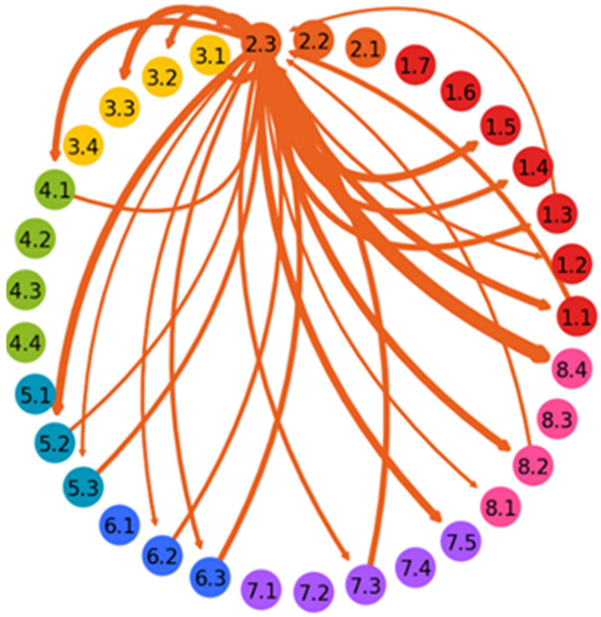


Link	*F*	Interpretation of the binding object
2.2 to 7.5	10.55	Heat and ventilation in buildings: techniques and alternative energy sources
2.2 to 4.1	4.36	Heat needs and production for greenhouse cultivation
2.2 to 7.4	3.76	X
2.2 to 8.4	2.87	X
2.2 to 8.2	2.73	X
2.2 to 6.1	2.51	X
2.2 to 4.4	2.22	Hydroponic production containers Constraints of a long winter
2.2 to 7.1	1.78	Temperature conditions affected by climate change and influencing energy needs

7.5. Resilience and housing quality in a northern climate, 4.1. Community projects to meet the challenges, 7.4. Disruption of caribou migration, 8.4. Aviation's social role for young people, 8.2. Dependence on airfreight supply, 6.1. Extractive activities: exploration, operation and site rehabilitation, 4.4. Nunavik's food system: limitations and prospects, 7.1. General impacts of climate change

Illustration of subclass interlinkages

2.3. Decentralised solar power: photovoltaic and thermal



Link	*F*	Interpretation of the binding object
2.3 to 8.4	9.15	X
2.3 to 5.2	4.31	Potential and prospects for wind power in Nunavik communities
2.3 to 8.2	4.11	X
2.3 to 1.1	4.03	Energy infrastructure projects for Nunavik communities
2.3 to 3.3	3.91	Installation and development of alternative energy projects such as solar and wind power
2.3 to 7.5	3.87	Research dedicated to adapting buildings to cold climates and to their energy facilities
2.3 to 1.5	3.87	X
2.3 to 3.1	3.47	Alternative energy projects including solar power to replace petroleum products in communities

8.4. Aviation's social role for young people, 5.2. Alternative energy development: stakeholders, governance and community participation, 8.2. Dependence on airfreight supply, 1.1. Investments in energy and infrastructure, 3.3. Mining sector: electricity and GHG emissions, 7.5. Resilience and housing quality in a northern climate, 1.5. Mining, forestry and energy industries, 3.1. Power generation and GHG emissions

Tableau 4.10 Interpretation of interlinkages for subclasses of class 3

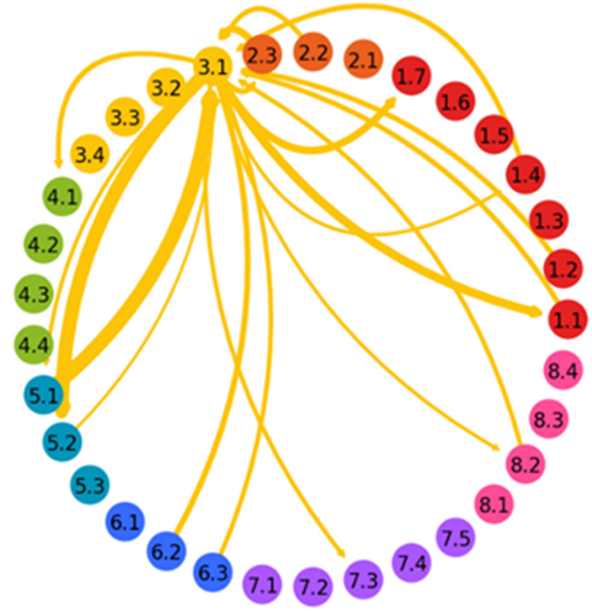
<table>
<tr><td colspan="3">Illustration of subclass interlinkages</td></tr>
<tr><td colspan="2">3.1. Power generation and GHG emissions</td><td>
</td></tr>
<tr><td>Link</td><td>F</td><td>Interpretation of the binding object</td></tr>
<tr><td>5.1 to 3.1</td><td>8.96</td><td>Power plant generation and conversion</td></tr>
<tr><td>3.1 to 5.2</td><td>8.60</td><td>Tarquti Energy's contribution to the development of renewable energy projects</td></tr>
<tr><td>3.1 to 1.1</td><td>4.60</td><td>Companies involved in the development of energy projects or aiming at socio-economic development in isolated communities.</td></tr>
<tr><td>3.1 to 1.7</td><td>3.49</td><td>Autonomy, supply and self-determination for Inuit society</td></tr>
<tr><td>2.3 to 3.1</td><td>3.47</td><td>Alternative energy projects including solar power to replace petroleum products in communities</td></tr>
<tr><td>6.2 to 3.1</td><td>2.41</td><td>X</td></tr>
<tr><td>3.1 to 2.3</td><td>2.20</td><td>Same as link 2.3 to 3.1</td></tr>
<tr><td>1.2 to 3.1</td><td>1.95</td><td>X</td></tr>
<tr><td colspan="3">5.1. Inukjuak hydroelectric project development, 5.2. Alternative energy development: stakeholders, governance and community participation, 1.1. Investments in energy and infrastructure, 1.7. Food insecurity, 2.3. Decentralised solar power: photovoltaic and thermal, 6.2. Waste management, 1.2. Infrastructure and sustainable socio-economic development</td></tr>
</table>

Illustration of subclass interlinkages

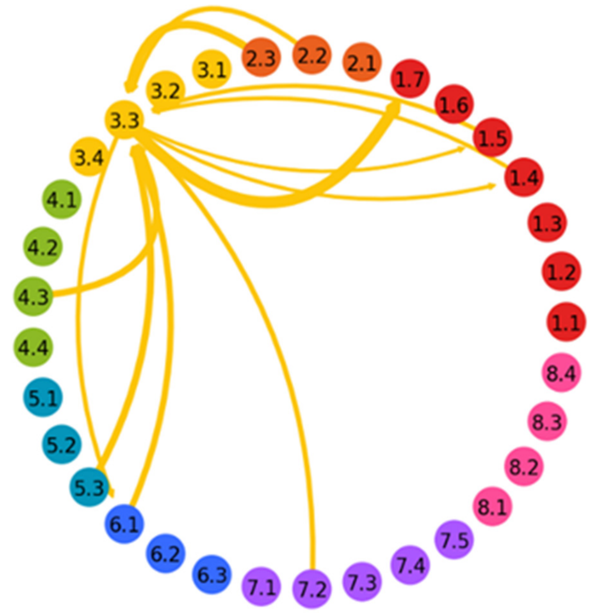
3.2 Energy costs and revenues

Link	*F*	Interpretation of the binding object
2.1 to 3.2	3.53	Cost of goods and services and cost of living
5.1 to 3.2	3.31	Direction, cost and financing of the construction of the Inukjuak hydroelectric power station
6.3 to 3.2	2.50	Social impacts or benefits from infrastructure or energy projects
2.3 to 3.2	2.48	X
3.2 to 7.4	1.39	X
6.2 to 3.2	0.82	Management and reuse of residual materials or waste

2.1. Building energy efficiency, 5.1. Inukjuak hydroelectric project development, 6.3. Assessment, consultation and protection mechanisms, 2.3. Decentralised solar power: photovoltaic and thermal, 7.4. Disruption of caribou migration, 6.2. Waste management

Illustration of subclass interlinkages

3.3. Mining sector: electricity and GHG emissions



Link	*F*	Interpretation of the binding object
3.3 to 1.7	6.69	X
2.3 to 3.3	3.91	Installation and development of alternative energy projects such as solar and wind power
5.3 to 3.3	3.37	Installation of alternative energy projects such as wind and hydro power
4.3 to 3.3	3.08	Constraints and prospects for socio-economic and energy development in the Arctic
6.1 to 3.3	2.76	Environmental impacts of mining activities
2.2 to 3.3	1.69	Constraints or benefits of cold temperatures on energy systems
3.3 to 6.1	1.47	*Same as link 6.1 to 3.3*
1.5 to 3.3	1.38	Mining development and related environmental impacts

1.7. Food insecurity, 2.3. Decentralised solar power: photovoltaic and thermal, 5.3. Managing water flows and reserves, 4.3. Adapting lifestyles to climate change, 6.1. Extractive activities: exploration, operation and site rehabilitation, 2.2. Heat production and storage, 1.5. Mining, forestry and energy industries

<table>
<tr><td colspan="3">Illustration of subclass interlinkages</td></tr>
<tr><td colspan="2">3.4. Energy storage for electricity</td><td>
</td></tr>
<tr><td>Link</td><td>F</td><td>Interpretation of the binding object</td></tr>
<tr><td>3.4 to 1.5</td><td>2.62</td><td>Reduced environmental impact economy and industries using new technologies</td></tr>
<tr><td>3.4 to 7.5</td><td>1.89</td><td>Specific needs and new clean technologies to meet them in northern, isolated or rural regions for residential buildings</td></tr>
<tr><td>2.2 to 3.4</td><td>1.32</td><td>X</td></tr>
<tr><td>1.5 to 3.4</td><td>0.38</td><td>Same as link 3.4 to 1.5</td></tr>
<tr><td colspan="3">1.5. Mining, forestry and energy industries, 7.5. Resilience and housing quality in a northern climate, 2.2. Heat production and storage</td></tr>
</table>

4.5.3 Final indicator selection

The selection step resulted in a set of 29 indicators. However, connections between the thematic subclasses and indicators could not be made easily. Indeed, the specific nature of the context and the local scale bring out topics that are not covered by existing indicators or references in the literature. Thus, some new indicators or descriptive tools are suggested. Furthermore, the limited statistical coverage of Nunavik currently limits the possibility of building a set that can be regularly updated. Also, the methodology for calculating some indicators depends on the available data. Therefore, their calculation or concatenation methodology remains to be defined.

Tableau 4.11 and Tableau 4.12 present the indicator selection for classes 2 and 3. The references listed in both tables are detailed in ANNEXE 4.d. Units associated with each indicator are provided as indicative, but equivalent units could be used. During the process, an empirical distinction was made between communities and mining sites. Firstly, subclasses 3.1 and 3.3 deal separately with electricity generation in the two sectors. This dichotomy is made directly within subclass 2.2 regarding heating. Finally, the nature of the indicator suggested in subclass 3.4 describing electricity storage allows the two sectors to coexist within.

Tableau 4.11 Indicators for class 2 representing residential energy and decentralised energy production

Sub-theme	Indicator	Ref.(1)	Data(2) (3)
Subclass 2.1 - Building energy efficiency	Financial aid for energy efficiency from local, provincial, or federal governments ($)	Original	No data
	Energy efficiency measures for housing (quantitative and qualitative)	Original	HQD (2022)
	Consumption of households per dwelling with climatic correction (MWh)	B	No data
	Useful consumption of households for space heating per degree-day per m^2 and per capita (MWh/unit)	B	HQ (2017)
	Construction standards for new housing (quantitative and qualitative)	Original	Lemieux-Montminy (2022), Société d'habitation du Québec (2018, 2020)
	Residential and commercial heating costs ($/kWh)	Original	No data

Sub-theme	Indicator	Ref.[1]	Data[2] [3]
Subclass 2.2 - Heat production and storage	Absolute value of annual fossil fuel consumption for building heating in communities (toe/year)	3, 5, 6	No data
	Share of renewable in heat production in communities (%)	3,6	No data
	Absolute value of annual fossil fuel consumption for greenhouse heating (toe/year)	3, 5, 6	No data
	Absolute value of annual fossil fuel consumption for mining sites heating (toe/year)	3, 5, 6	No data
	Share of renewable in heat production in mining sites (%)	3,6	No data
Subclass 2.3 - Decentralised solar power: photovoltaic and thermal	Role of communities and stakeholders involved in solar panels development (qualitative)	Original, C, D	No data
	Quantitative and qualitative description of current projects - Type of system - Nameplate power capacity (MW) - Steps validated and to be completed before commissioning	Original	No data

(1) The references provided could include works that either explicitly describe or use the selected indicator, or documents that served as underlying inspiration for the indicator.
(2) In this context, little data is available, causing some references to provide only partial data or local application advice.
(3) "No data" indicates that no data was found, but it's possible that data exists or simply needs to be compiled.

Tableau 4.12 Indicators for class 3 representing centralised energy production

Sub-theme	Indicator	Ref.[1]	Data[2] [3]
Subclass 3.1 - Power generation and GHG emission in communities	Installed capacity - Total installed capacity (MW) - Fuel shares in electricity installed capacity (%)	5, 9, 10, 15, 16, A	HQD (2022)
	Electricity generation - Total gross electricity generation (GWh/year) - Fuel shares in electricity generation (%)	4, 5, 9, 13, 14, 15, 18, A	HQD (2022)
	Growth in customer numbers and demand (%/year)	Original	HQD (2022)
	GHG emissions from electricity production - Absolute value (tCO_2 eq./year) - Per capita (tCO_2 eq./capita) - Per unit of GDP ($kgCO_2$ eq./\$) - Per kWh of generated electricity ($kgCO_2$ eq./kWh)	4, 5, 10, 13, 14, 15	HQD (2022), MAMH (2023), Robichaud and Duhaime (2015)
	Quantitative and qualitative description of current alternative projects (e.g. wind, solar, hydropower) - Planned installed capacity (MW) - Expected annual production (GWh/year) - Expected GHG emissions saved (tCO_2 eq.) - Steps validated and to be completed before commissioning	Original	HQD (2022), CQEK (2022a, 2022c, 2023, 2022)
	Role of communities and stakeholders involved in electricity generation (qualitative)	Original, C, D	Harbour-Marsan (2018)

Sub-theme	Indicator	Ref.[(1)]	Data[(2)(3)]
Subclass 3.2 - Energy prices and access to energy and other utilities	Electricity sales revenue for each relevant stakeholder ($)	Original, 18	No data
	End-use energy prices by fuel and by sector ($/MWh)	5	HQ (2022), KRG and Makivik (2022), Régie de l'énergie (2023)
	Prices Index for food, housing, transportation, household expenses, and social activities	Original	Robitaille and al. (2016; 2018; 2018; 2018; 2018)
	Subsidies for residents - Program description - Subsidy values by type and per unit ($/MWh)	Original	KRG (2021a, 2021b, 2021c, 2021d), KRG and Makivik (2022)
Subclass 3.3 - Mining sector: electricity and GHG emissions	Installed capacity - Total installed capacity (MW) - Fuel shares in electricity installed capacity (%)	5, 9, 10, 15, 16, A	CQEK (2022a, 2022b, 2022c), CQEK and Canadian Royalties (2022), Azin (2022), Tardy (2022), Robert (2023)
	Electricity generation - Total gross electricity generation (GWh/year) - Fuel shares in electricity generation (%)	4, 5, 9, 13, 14, 15, 18, A	
	GHG emissions from electricity production - Absolute value (tCO_2 eq./year) - Per capita (tCO_2 eq./capita) - Per unit of GDP ($kgCO_2$ eq./$) - Per kWh of generated electricity ($kgCO_2$ eq./kWh)	4, 5, 10, 12, 13, 14, 15	
	Final energy consumption in the transport sector by fuel and mode of transport (toe/year)	B, E, F, G, 18	No data

Sub-theme	Indicator	Ref.[1]	Data[2][3]
Subclass 3.4 - Energy storage for electricity	Quantitative and qualitative description of current projects - Type of system - Nameplate power capacity (MW) - Nameplate energy capacity (GWh) - Steps validated and to be completed before commissioning - Mean initial project costs per unit ($/GWh)	Original, H	EVLO (2023), Tugliq Energie (2016, 2019, n. d.)
	Description of vehicle-to-grid projects (qualitative)	Original	No data
(1) The references provided could include works that either explicitly describe or use the selected indicator, or documents that served as underlying inspiration for the indicator. (2) In this context, little data is available, causing some references to provide only partial data or local application advice. (3) "No data" indicates that no data was found, but it's possible that data exists or simply needs to be compiled.			

4.6 Discussion

4.6.1 Main results of the application test

Among the six criteria introduced by Gunnarsdóttir and al. (2020), this practical test demonstrates adherence to at least five. Indicators are transparently selected individually, utilising information elements interpreted through the IRaMuTeQ software. Additionally, the results of interpretations are detailed in ANNEXE 4.b, with the necessary material for replication provided (i). Indicator selection is also guided by a thematic framework constructed to structure the set (ii). This framework is simpler to construct compared to Neves and Leal's (2010) local approach. The press corpus demands minimal resources, and IRaMuTeQ software significantly facilitates theme extraction and interpretation. It encompasses at least the three dimensions of economic, social, and environmental, with further representation of context-specific issues (iii). For instance, northern industries impact the economic dimension, while cultural and political issues intertwine with social, environmental dimensions, and the energy challenge. This interweaving is also represented by the described interlinkages, which also offer potential for coordinating indicator selection based on thematic classes (iv). Finally, stakeholder analysis is integrated through the analysis of press discourse (v).

The last criterion, concerning the transparency of the application, could not be validated in this methodological test, but it could be if the approach were fully implemented. This would entail defining indicator application methodologies, including calculations, and necessary data sources. However, this overall criterion is closely linked to two indicator assessment criteria (see section 4.4.3.3) which encounter obstacles associated to the specific context of local scale: “Data availability and quality” and “Grounded in research”. This issue is perhaps part of a larger methodological gap that is further discussed in section 4.6.2.

4.6.2 Limitations and recommendations for framework building and indicator selection

Indigenous interests related to environmental or energy issues are not fairly represented at supra-local scales (Greg Lowan-Trudeau, 2021; Gregory Lowan-Trudeau and Fowler, 2021; C. Walker and al., 2019). Thus, the integration of the local press in the construction of the thematic framework is an asset of representativeness. However, it does not free the framework from biases. In particular, class 8 seems to present a one-sided view of aviation as it does not present any environmental or energy aspect of sustainability. It sheds light on the limitations of the press discourse based approach which does not guarantee the representativeness of sustainability in the thematic framework.

In addition, the structure of the thematic framework could be made clearer and more effective. The HCAs have produced useful results, but their relevance could be improved. The thematic classes tend to separate things that could be said together, or to overlap. For example, the indicators in subclass 3.1 are dedicated to a complete assessment of electricity production, whereas the thematic framework implied separating generation methods. For example, the framework isolated solar energy under subclass 2.3. Conversely, this subclass also includes solar thermal, whereas thermal energy is the theme associated with subclass 2.2, highlighting an overlap. Also, the mining sector is treated unevenly. It is given a subclass for electricity generation but not for the other themes (subclasses 2.2, 2.3, 3.4), which can lead to confusion between communities' grids and mining sites. Finally, wind energy was included in subclasses 3.1 and 3.3 but its place was not explicitly fixed by the framework.

Then, selecting context-appropriate indicators proves to be challenging, even though it relies on guidelines and selection criteria. Firstly, the indicator bank provided by Chaubier and al. (submitted, not published) mainly includes national-scale indicators, and it is difficult to find references offering indicators as specific as needed or suitable for local scales. Nevertheless, the simplest and most coherent approach sometimes appears to be creating a new indicator. Secondly, some subclasses lead to large concepts or very precise subjects that are difficult to describe with indicators or which significance is discussable. For example, the "role of communities and stakeholders involved in electricity generation" and the "solar panel efficiency in the north" (see are respectively large and very specific. Thirdly, some indicators tend to bridge multiple disciplines, and most thematic classes in the framework address dimensions beyond the technical one. Multidisciplinary expertise is therefore required.

To address these challenges, some methodological improvements can be made. Firstly, involving a group of Nunavik experts or stakeholders with expertise in aspects of the thematic framework, or a larger multidisciplinary research team, would enhance the robustness and relevance of the final indicator set. This involvement could be integrated following the framework construction. On the one hand, it could help refine and clarify the thematic framework to make it more robust and representative. Moreover, structuring references about sustainability aspects of each theme could be used. On the other hand, a broader participation could reinforce the relevance of indicator selection or creation, as well as help finding or building data sources to calculate them. More precisely, working with energy or public actors could help collect or get access to data. Furthermore, it could help answer questions about what is most relevant to describe some subclasses of the framework. Indeed, qualitative indicators or descriptions seem more suitable than quantitative indicators for some of them. Secondly, guidelines on how to interpret the subclasses content would be useful to differentiate a discussed subject of a local issue of sustainability. For example, the solar panel efficiency is a discussed subject but is less an issue than the installed capacity of solar power.

To conclude, it appears that criteria “Data availability and quality” and “Grounded in research” are not completely applicable for local context which needs specific description indicators or tools. Following these observations, a new set of criteria should be defined to assess indicator selection in future research.

4.6.3 Limitations and recommendations for identifying interlinkages

Finally, this case study has highlighted some perspectives for improving the evaluation of interlinkages. The number of interlinkages per subclass has shown significant variation, resulting in an excessive number for some cases. This contrast is amplified by the difference in size between subclasses. First, the larger a subclass is, the more likely it is to include echoes from another class because it is based on a larger number of lexical forms. Moreover, these lexical forms tend to have a larger χ^2 value and therefore are more likely to pass the threshold test (4.2) defined in section 4.4.3.2. Only the parameter τ can adjust this test, but it would result in reducing the number of interlinkages for all subclasses, making it impossible to identify interlinkages for some. Thus, practical and theoretical modifications are proposed to better parameterise the identification of interlinkages.

Firstly, there is no need to consider interlinkages between two subclasses from the same primary class because they are particularly obvious due to the proximity of the subclasses and because they do not provide significant assistance. Additionally, reciprocal interlinkages between two classes could be merged because they carry the same meaning. Secondly, two new parameterisations are conceivable. The first would be to limit the number of characteristic forms among which a lexical echo could be detected in the target classes. In practice, if the echoes of n characteristic forms from one class are sought, they would be searched among the m characteristic classes of the other classes, with m to be defined depending on the application. The second option would be to weigh the value of $\chi^2{}_{echo}$ in the threshold test of equation (4.2).

This would aim to take into account the potential shift between the χ^2 values of the original class and the class containing the echo.

4.7 Conclusion

The method developed by Chaubier and al. (submitted, not published) shows its effectiveness in constructing a set of indicators capable of monitoring the energy transition process at a local scale, as well as other dimensions of sustainability. However, some improvements are suggested. In particular, Chaubier and al. (submitted, not published) already asked whether the study of the press could be equivalent to the integration of stakeholders as suggested by Gunnarsdóttir and al. (2021). This study does not answer this question in terms of representativeness, but rather in practical terms. It seems that the analysis of press discourse is sufficient to construct a framework for selecting indicators, but this framework is sensitive to the biases introduced by the press. A refinement stage based on reference documentation or on the opinion of experts or stakeholders would therefore be enriching, or even necessary. Furthermore, the finalisation of the set and its applicability in a local context could also require the participation of local stakeholders or actors with expertise in certain subjects and the region. Nevertheless, the press study approach has proved to considerably simplify the construction of a first version of the selection framework, or even of a set of indicators. In the case of Nunavik, this could benefit the development of a data collection strategy (Farsari and Prastacos, 2002).

In order to produce a set of truly applicable indicators for Nunavik, the results of this study could be taken up and refined as suggested in the recommendations in sections 4.6.2 and 4.6.3. This method also produces data that can be used for further analysis. In particular, the interlinkages have structural implications or are linked to stakeholders' perceptions. This approach is likely to contribute to the necessary implementation of a transition policy in the Nordic region, by facilitating the emergence of a shared vision (Serran and al., 2019). Moreover, an application to other northern Canadian territories could be envisaged and would be relevant. In particular, Nunavut has common points with Nunavik and is a potential field of application (Byrne, 2018; Cherniak, 2015).

CONCLUSION

La transition énergétique est un processus qui imbrique les dimensions techniques, sociales, culturelles, économiques, ou encore politiques, ainsi que des enjeux situés dans l'espace et le temps. Les séries d'indicateurs ont le potentiel de représenter la diversité et la complexité de ces aspects. Elles constituent donc des outils d'analyse pertinents pour le programme ENERGON qui vise à dépasser les approches analytiques en silo disciplinaire. Cependant, les séries existantes ont des défauts structurels et ne traitent pas des échelles infranationales. Or, ENERGON s'intéresse exclusivement à des transitions énergétiques dont l'influence est locale ou régionale. Cette recherche a donc visé à identifier ou développer une méthode apte à construire une série d'indicateurs de suivi d'une transition énergétique à de telles échelles. Si les six territoires d'application du programme se répartissent entre plusieurs régions françaises, le comté du Pima County aux États-Unis, et la région du Nunavik, seule cette dernière a été utilisée comme terrain d'expérimentation dans le cadre de ce projet de maîtrise.

Sur la base des limites de la littérature actuelle, une nouvelle méthode a finalement été développée. En faisant l'hypothèse que le discours de presse permet de porter la voix des parties prenantes et d'ancrer l'approche dans le contexte, une étude quantitative et qualitative des journaux locaux est proposée comme socle méthodologique. Pour ce faire, les outils d'analyse du logiciel IRaMuTeQ ont été exploités. En particulier, la classification hiérarchique descendante est un outil permettant de construire un cadre thématique. Elle vise à identifier les thèmes émergents d'un corpus de textes, en séparant les groupes de textes les plus différents, jusqu'à ce que seuls des groupes de textes semblables ne subsistent. Une interprétation de ces groupes de textes permet alors de déterminer les classes lexicales thématiques structurantes des enjeux de durabilité entourant la transition énergétique dans un contexte local. Ensuite, une méthode a été créée spécialement pour évaluer les interactions internes à ce cadre thématique, permettant ainsi d'affiner la sélection des indicateurs. Elle s'appuie sur les données issues de la classification hiérarchique descendante, et analyse les échos du lexique d'une classe thématique, dans une autre. Le cadre thématique construit, prenant en compte les interactions entre ses thèmes structurants, permet alors de réaliser une sélection cohérente d'indicateurs adaptée au contexte. Globalement, la méthodologie développée présente l'avantage de pouvoir être appliquée dès lors qu'une presse locale ou couvrant le territoire d'étude est disponible. Il est cependant recommandé de prendre connaissance du système énergétique de celui-ci, ainsi que du contexte socio-économique et des enjeux locaux de durabilité. En effet, cela permet d'identifier les sources de données utiles et de faciliter les interprétations à la lumière du contexte.

Ainsi, un tel état des lieux a été dressé pour le Nunavik, un grand territoire isolé, nordique, et faiblement peuplé. Il est marqué par des conditions socio-économiques nettement moins avantageuses que dans le reste du Québec. Les 15 communautés autochtones qui y résident tentent de concilier développement et préservation de leur identité culturelle, largement associée à l'environnement ainsi qu'à certaines pratiques traditionnelles. Par ailleurs, ce développement dépend en partie de l'approvisionnement énergétique contraint de la région. Isolé du réseau électrique intégré du Québec et de ses routes terrestres, le système énergétique du Nunavik repose majoritairement sur des produits pétroliers, malgré l'émergence de projets visant à réduire cette dépendance depuis les années 1980. Ce schéma énergétique a plusieurs conséquences, environnementales et socio-économiques entre autres, étant responsable d'émissions de gaz à effet de serre, et d'un accès limité à l'électricité. Aussi, la région compte deux complexes miniers qui présentent le même *pattern* énergétique que les communautés. Malgré ces enjeux, le territoire souffre d'une faible couverture statistique, freinant la possibilité d'étudier la question énergétique à une échelle macro-économique, et de dessiner une trajectoire de transition. Seule la société Hydro-Québec annonce un objectif de conversion des réseaux de production d'électricité à des modes de production renouvelable pour 2030. Cependant, bien que des initiatives communautaires prometteuses aient émergé, le nombre et l'ampleur des projets de conversion actuels laissent à penser que cet objectif ne puisse être atteint.

Ce contexte, parmi d'autres facteurs, a eu un impact sur la façon dont la méthodologie a été appliquée au cas d'étude. En particulier, la faible couverture statistique de la région est un frein notable au développement d'une série d'indicateurs. Ainsi, cette application a pris la forme d'une approche exploratoire visant à identifier les limites et perspectives d'amélioration de la méthodologie. D'abord, un corpus de presse locale, provinciale, et nationale centrée autour du Nunavik et de l'enjeu énergétique a été élaboré. Puis, une classification hiérarchique descendante lui a été appliquée. Elle a abouti à la création d'un cadre thématique structuré par huit classes thématiques principales, elles même divisées en un total de 33 sous-classes thématiques. Ce cadre intègre et imbrique bien la diversité des dimensions associées à une telle transition. En particulier, les aspects culturels et de gouvernance de l'environnement, ou encore les enjeux sociaux spécifiques au Nunavik y apparaissent. De plus, les interactions évaluées entre chaque thème illustrent leur imbrication et se montrent susceptibles de faire une sélection d'indicateurs cohérente entre les thèmes. Une sélection d'indicateurs a ainsi été réalisée pour deux des huit classes principales, englobant sept sous-thèmes. Celles-ci couvraient les problématiques de production d'électricité et de chaleur, centralisée et décentralisée, dans les communautés et dans les complexes miniers. Finalement, 28 indicateurs ont été sélectionnés pour effectuer le suivi de ces classes thématiques. Cependant, le manque de sources de données a été un frein à cette sélection et la liste d'indicateurs produite reste à être affinée, et ses directives d'application définies.

Par ailleurs, le cadre thématique construit sur la base du discours de presse a montré qu'il était susceptible d'introduire des biais et que sa structure pouvait être raffinée, ou complétée. D'une part, un des huit thèmes structurants du cadre, dédié à l'aviation, profite d'une vue subjective de la part des parties prenantes qui l'ont introduit au corpus initial. En effet, un journal local lui offre une couverture médiatique importante, et évoque quasi-exclusivement ses bénéfices sociaux. Or, le secteur aérien a aussi une influence sur d'autres dimensions, notamment sur le plan environnemental. D'autre part, la structure du cadre thématique semble pouvoir être optimisée pour améliorer sa lisibilité. Par exemple, le cas du secteur minier est traité à part quant à la production d'électricité, mais pas quant à la production de chaleur. Il conviendrait d'établir des divisions plus claires par endroit. Enfin, si un thème ou sous-thème du cadre soulève effectivement un enjeu local et ancré dans le contexte, une mise en cohérence supplémentaire avec le contexte pourrait aussi améliorer sa représentativité.

En somme, il a été suggéré que le cadre thématique, ainsi que la sélection d'indicateurs, pouvaient être raffinés ou éclaircis en faisant appel à une documentation structurante, ainsi qu'à des acteurs ou experts du Nunavik en lien avec les enjeux de durabilité. En particulier, certaines parties prenantes ou experts sont susceptibles de fournir des sources de données ou d'apporter des pistes de solution pour en construire. Bien que l'étude du discours de presse montre son efficacité pour structurer la démarche de sélection d'indicateurs et construire des résultats préliminaires, cette recherche souligne le manque qui peut être adressé par une véritable implication de parties prenantes ou d'experts. Malgré tout, l'approche proposée peut être appliquée telle qu'elle est aujourd'hui pour d'autres bénéfices qu'elle est susceptible d'apporter. En effet, elle peut guider la mise sur pieds d'une stratégie de collecte de données, aider à définir des objectifs de transition, ou participer à la construction d'une vision commune de la durabilité.

ANNEXE 2.a

ALGORITHMES PYTHON

Algorithme-A 2.a-1 Data extraction and analysis of interlinkages

```
import numpy as np
import pandas as pd
import xlrd as xlrd
import openpyxl
import matplotlib.pyplot as plt

from openpyxl import workbook as wb
from openpyxl import load_workbook
from openpyxl.utils import get_column_letter

#### Data Loading

# Read the Excel file
file_path = 'C:\\Users\\Deliverable\\Subclasses_analysis.xlsx' #Change for the right adress.
df = pd.read_excel(file_path)
wb = load_workbook(file_path)

## Definitions and Parameters to Adjust

num_rows = 22 # Number of forms studied for each class +1
num_classes = 33 # Total number of classes studied. Change for ther right number.
threshold = 1.5 # Value of the "tau" parameter (adjust as needed)

# Use the list "sheets" to iterate through the sheets in the workbook
sheets = [wb[sheet_name] for sheet_name in wb.sheetnames]
print(sheets)

## Data Extraction

L = [[] for _ in range(num_classes)] # Create a list of empty lists

for c, sheet in enumerate(sheets):
for row in range(2, num_rows + 1):
line = []
for col in [1, 5, 7]:
column_letter = get_column_letter(col)
cell_value = sheet[column_letter + str(row)].value
line.append(cell_value)
```

```
L[c].append(line)

for lst in L:
for item in lst:
item[1] = float(item[1])

print("Sheet", wb.sheetnames[0], "=", L[0])
print('')
print("Sheet", wb.sheetnames[int(num_classes/2)-1], "=", L[int(num_classes/2)-1])
print('')
print("Sheet", wb.sheetnames[-1], "=", L[-1])

## Detection of Echoes and Writing to Excel File

created_tables = [] # List to store the names of created tables
tables = [] # List to store table data

for i, sheet_i in enumerate(sheets):
table = {"forms": [], "chi2a": [], "Class b": [], "chi2b": [], "Chi2a/Chi2b Ratio": []}
chi2_min = float(L[i][num_rows - 2][1])

waiting_sheets_before = sheets[:i] # Sheets before sheet i
waiting_sheets_after = sheets[i + 1:] # Sheets after sheet i
waiting_sheets = waiting_sheets_before + waiting_sheets_after

for row_i in L[i]:
form_i = row_i[2]
chi2_i = row_i[1]

for sheet_j in waiting_sheets:
# Access sheet j in the Excel file
ws_j = wb[sheet_j.title]

# Iterate through cells in column "G" (which contains the forms)
for cell_j in ws_j['G']:
form_j = cell_j.value
if form_i == form_j:
# Retrieve chi2_j value from column "E" (previous column)
chi2_j = float(ws_j.cell(row=cell_j.row, column=cell_j.column - 2).value)

if chi2_j >= threshold * chi2_min:
table["forms"].append(form_i)
table["chi2a"].append(chi2_i)
table["Class b"].append(sheet_j.title)
```

```
table["chi2b"].append(chi2_j)
table["Chi2a/Chi2b Ratio"].append(chi2_j / chi2_i)

if len(table["forms"]) > 0:
table_name = f"table_{sheet_i.title}_{i}" # Indicates the origin class and its position in L
created_tables.append(table_name)
print(f"Table {table_name} has been created.")
print(f"Forms: {table['forms']}")
print(f"Class b: {table['Class b']}")
print()
tables.append((table_name, table)) # Add table name and data to the list
else:
# If the table is empty, add a row with "Empty" for each column
table["forms"].append("Empty")
table["chi2a"].append("Empty")
table["Class b"].append("Empty")
table["chi2b"].append("Empty")
table["Chi2a/Chi2b Ratio"].append("Empty")
tables.append((f"table_{sheet_i.title}_{i}", table)) # Add table name and data to the list

if len(created_tables) > 0:
print("The following tables have been created:")
for table_name in created_tables:
print(table_name)
else:
print("No tables have been created.")

# Include the tables in the corresponding Excel sheets
for table_name, table in tables:
header = ["Forms", "Chi2a", "Class b", "Chi2b", "Chi2a/Chi2b Ratio"]
sheet_name = table_name.split('_')[1] # Retrieve original sheet name from table name
ws = wb[sheet_name]

# Delete all columns after column I
max_col = ws.max_column
if max_col > 8: # If the sheet contains columns after column I (index 9)
ws.delete_cols(9, max_col - 8)

# Reinsert columns with the correct header
for col, hdr in enumerate(header, start=9): # Columns I, J, K, L, M (index 9 to 13)
if col > ws.max_column: # If the column doesn't exist, insert it
ws.insert_cols(col)
ws.cell(row=1, column=col, value=hdr)

# Write the data
```

```
for row_idx in range(len(table["forms"])):
for col_idx, key in enumerate(table):
ws.cell(row=row_idx + 2, column=col_idx + 9, value=table[key][row_idx])

# Save the modifications to the Excel file
wb.save(file_path)

## Calculation of Interrelations between Classes

wb = load_workbook(file_path)

# Iterate through each sheet in the Excel file
for sheet_name in wb.sheetnames:
ws = wb[sheet_name]

# Delete old data (columns O, P, Q)
ws.delete_cols(15, 3)

# Check if the table is empty
if ws.max_row < 2 or ws.max_column < 13:
continue # Ignore empty tables

# Read data from the existing table
tab1 = []
for row in ws.iter_rows(min_row=2, max_row=ws.max_row, min_col=9, max_col=13):
forms = row[0].value
chi2a = row[1].value
class_b = row[2].value
chi2b = row[3].value
ratio = row[4].value
tab1.append([forms, chi2a, class_b, chi2b, ratio])

# Check if the table is empty
if len(tab1) == 0:
continue # Ignore empty tables

# Create the new tab2 table
tab2 = [["Class a", "Class b", "Link Strength"]]

# Iterate through rows of tab1
for row in tab1:
class_b = row[2]
ratio = row[4]

# Check if ratio is None
```

```
if ratio is None:
continue # Ignore rows with None ratio

# Check if class_b already exists in tab2
exists = False
for tab2_row in tab2[1:]:
if tab2_row[1] == class_b:
exists = True
tab2_row[2] += ratio # Add ratio value to existing sum
break

# If class_b doesn't exist, add a new row to tab2
if not exists:
tab2.append(["", class_b, ratio])

# Insert the tab2 table into columns O, P, Q
for i, row in enumerate(tab2, start=1):
if i == 1:
ws.cell(row=i, column=15, value="Class a") # Header "Class a"
else:
ws.cell(row=i, column=15, value=ws.title if row[1] and row[2] else "") # Column O
ws.cell(row=i, column=16, value=row[1]) # Column P
ws.cell(row=i, column=17, value=row[2]) # Column Q

# Save the modifications to the Excel file
wb.save(file_path)
```

Algorithme-A 2.a-2 Display of interlinkages between classes and subclasses

```
imp import numpy as np
import pandas as pd
import math
import xlrd as xlrd
import openpyxl
import matplotlib.pyplot as plt

from openpyxl import workbook
from openpyxl import load_workbook
from openpyxl.utils import get_column_letter

import matplotlib.patches as patches
import matplotlib.transforms as transforms
```

```
## Parameters and Definitions

scale = 0.6 # Scale factor for lw (arrow thickness)
arrow_circle_gap = 18 # Distance between arrow tip and circle
neighbors_limit = 4 # Threshold number of circles separating two connected circles above
which arrows are drawn as if not neighbors

sheet_names = wb.sheetnames

# Circle positioning
circle_or_arc = 2 # Below 2, the figure is an arc.
angles = np.linspace(0, circle_or_arc * np.pi, len(sheet_names), endpoint=False)
x = np.cos(angles)
y = np.sin(angles)

sheet_coordinates = {sheet_name: (x[i], y[i]) for i, sheet_name in
enumerate(sheet_names)}

#sizes
circle_size = 0.05
font_size=10
max_arrows = 12 # Maximum size of the legend

## Functions

# Function to calculate the value of arc3_rad based on the number of circles separating two
connected circles
def calculate_arc3_rad(index1, index2, total_circles, scale):
num_circles_separation = min(abs(index2 - index1), total_circles - abs(index2 - index1))
if num_circles_separation <= neighbors_limit:
if num_circles_separation == 0:
arc3_rad = 0.5
else:
arc3_rad = 0.5 * (num_circles_separation + 4) / (num_circles_separation + 1)
else:
arc3_rad = 0.2
return arc3_rad

# Generate a color palette based on the leading digits of sheet names
def get_color(name):
colors = {
'1': '#E32322',
'2': '#EA601F',
'3': '#FCC509',
```

```
'4': '#8CBA26',
'5': '#0595BA',
'6': '#376BFF',
'7': '#AB57FF',
'8': '#FD4D98',
}

# Additional colors for digits > 8
extra_colors = ['#FF6633', '#33CC33', '#FF3300', '#FF66CC', '#3399FF', '#9933CC',
'#FF9933', '#99CC33']

# Convert the name to a string
name_str = str(name)

first_digit = name_str[0]
if first_digit.isdigit():
if first_digit in colors:
return colors[first_digit]
else:
# Use an additional color if the digit goes beyond 8
color_index = int(first_digit) % len(extra_colors)
return extra_colors[color_index]
else:
return 'cornflowerblue'

## Complete Display

#parameters

sheet_coordinates = {sheet_name: (x[i], y[i]) for i, sheet_name in
enumerate(sheet_names)}

# Dictionary to store arrows by tab group
grouped_arrows = {}

# Search for arrows departing from current tabs
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 is empty
if ws['P2'].value == "Empty":
continue # Ignore empty tables

# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
```

```
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Find the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
autre_index = sheet_names.index(class_b)

# Calculate the value of arc3_rad proportional to the number of circles separating the two
connected circles
arc3_rad = calculate_arc3_rad(index, autre_index, len(sheet_names), scale)

# Get the color of the arrow based on the current tab
color_outgoing = get_color(sheet_name)

# Add the arrow to tab groups for arrows departing from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append(((x[index], y[index]), (x[autre_index],
y[autre_index]), Link_Strength[j], arc3_rad, color_outgoing))

# Search for tabs that have the current tab in their "Classe b" column
for k, other_sheet_name in enumerate(sheet_names):
if other_sheet_name == class_b:
# Add arrows for tabs arriving at current tabs
if class_b not in grouped_arrows:
grouped_arrows[class_b] = []
grouped_arrows[class_b].append(((x[index], y[index]), (x[autre_index], y[autre_index]),
Link_Strength[j], arc3_rad, color_outgoing))

# Create the figure for all arrows
fig, ax = plt.subplots(figsize=(8, 8))
ax.set_xlim(-1.1, 1.1)
ax.set_ylim(-1.1, 1.1)
```

```
ax.set_aspect('equal')

# Add circles below arrows (zorder=1) with associated colors
for i, sheet_name in enumerate(sheet_names):
color = get_color(sheet_name)
ax.add_patch(plt.Circle((x[i], y[i]), circle_size, color=color, zorder=1))
ax.annotate(sheet_name, (x[i], y[i]-0.01), ha='center', va='center', fontsize=font_size,
zorder=1)

# List to store all arrows
all_arrows = []

# Add arrows for each tab group
for sheet_name in sheet_names:
arrows = grouped_arrows.get(sheet_name, [])
all_arrows.extend(arrows)
for arrow in arrows:
start, end, force, arc3_rad, color_outgoing = arrow
fleche = ax.annotate("", xy=end, xytext=start, arrowprops=dict(arrowstyle='simple',
color=color_outgoing, lw=scale * force, connectionstyle=f"arc3,rad={arc3_rad}",
shrinkA=0, shrinkB=arrow_circle_gap))
fleche.set_zorder(0)

# Figure settings
ax.axis('off')

plt.show()



## Complete Display with Legend

# Dictionary to store arrows by tab group
grouped_arrows = {}

# Searching for arrows originating from current tabs
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 array is empty
if ws['P2'].value == "Empty":
continue # Ignore empty arrays

# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
```

```
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Search the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
other_index = sheet_names.index(class_b)

# Calculate the arc3_rad value proportional to the number of circles separating the two
connected circles
arc3_rad = calculate_arc3_rad(index, other_index, len(sheet_names), scale)

# Get arrow color based on current tab
color_outgoing = get_color(sheet_name)

# Add arrow to tab groups for arrows originating from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append(((x[index], y[index]), (x[other_index],
y[other_index]), Link_Strength[j], arc3_rad, color_outgoing))

# Search for tabs that have the current tab in their "Classe b" column
for k, other_sheet_name in enumerate(sheet_names):
if other_sheet_name == class_b:
# Add arrows for tabs arriving at current tabs
if class_b not in grouped_arrows:
grouped_arrows[class_b] = []
grouped_arrows[class_b].append(((x[index], y[index]), (x[other_index], y[other_index]),
Link_Strength[j], arc3_rad, color_outgoing))

# Create the figure for all arrows
fig, ax = plt.subplots(figsize=(20, 12))
ax.set_xlim(-1.1, 1.1)
ax.set_ylim(-1.1, 1.1)
```

```
ax.set_aspect('equal')

# Add circles below arrows (zorder=1) with associated colors
for i, sheet_name in enumerate(sheet_names):
color = get_color(sheet_name)
ax.add_patch(plt.Circle((x[i], y[i]), circle_size, color=color, zorder=1))
ax.annotate(sheet_name, (x[i], y[i]), ha='center', va='center', fontsize=font_size, zorder=1)

# List to store all arrows
all_arrows = []

# Add arrows for each tab group
for sheet_name in sheet_names:
arrows = grouped_arrows.get(sheet_name, [])
all_arrows.extend(arrows)
for arrow in arrows:
start, end, force, arc3_rad, color_outgoing = arrow
arrow = ax.annotate("", xy=end, xytext=start, arrowprops=dict(arrowstyle='simple',
color=color_outgoing, lw=scale * force, connectionstyle=f"arc3,rad={arc3_rad}",
shrinkA=0, shrinkB=arrow_circle_gap+circle_size*120))
arrow.set_zorder(0)

# Figure settings
ax.axis('off')

# Add legend inside the rectangle
legend_texts = []
# Use the sorted() function with the key parameter to sort based on the first element of
each sublist
all_arrows = sorted(all_arrows, key=lambda x: x[2], reverse=True)
for arrow in all_arrows[:max_arrows]:
start, end, force, _, _ = arrow
start_sheet_name = None
end_sheet_name = None

# Find the starting tab name associated with the "start" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == start:
start_sheet_name = sheet_name
break

# Find the ending tab name associated with the "end" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == end:
end_sheet_name = sheet_name
```

```
break

# Handle the case where the tab name is not found for the starting or ending coordinates
if start_sheet_name is None:
start_sheet_name = "Unknown"
if end_sheet_name is None:
end_sheet_name = "Unknown"

link_text = f"Link {start_sheet_name} to {end_sheet_name:<4}: F = {force:.2f}"
legend_texts.append(link_text)

# Add rectangle to the right of the figure
rect_width = 0.15
rect_height = (0.07 + 0.042 * (len(legend_texts) - 1)) * (-1)
rect_left = 0.69 # Adjust the value as needed
rect_bottom = 0.78
rect = patches.Rectangle((rect_left, rect_bottom), rect_width, rect_height,
transform=fig.transFigure, facecolor='white', edgecolor='black', linewidth=2.0, zorder=-1)
fig.patches.append(rect) # Add the rectangle directly to the figure

# Adjust margins for the text
rect_margin = 0.00
text_margin = 0.31 # Adjust this value as needed

trans = transforms.blended_transform_factory(ax.transAxes, fig.transFigure)
for i, text in enumerate(legend_texts):
text_y = rect_bottom - (i + 1) * (0.5 - 2 * rect_margin) / max_arrows
ax.text(rect_left + rect_width + text_margin, text_y, text, ha='left', va='center',
fontsize=16, transform=trans)

plt.subplots_adjust(right=0.75) # Adjust the position of the figure to make room for the
legend

plt.show()



## Display by Subclass - Arrows originating from the Subclass with Legend

# List of tab names
sheet_names = wb.sheetnames

# Dictionary to store arrows by tab group
grouped_arrows = {}
```

```
# Searching for arrows originating from current tabs
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 array is empty
if ws['P2'].value == "Empty":
continue # Ignore empty arrays

# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Search the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
other_index = sheet_names.index(class_b)

# Calculate the arc3_rad value proportional to the number of circles separating the two
connected circles
arc3_rad = calculate_arc3_rad(index, other_index, len(sheet_names), scale)

# Get arrow color based on current tab
color_outgoing = get_color(sheet_name)
color_incoming = get_color(class_b)

# Add arrow to tab groups for arrows originating from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append(((x[index], y[index]), (x[other_index],
y[other_index]), Link_Strength[j], arc3_rad, color_outgoing))


# Create figures for each tab group
```

```
for sheet_name in sheet_names:
# Use get() to retrieve arrows associated with the tab, using an empty list as the default
value
arrows = grouped_arrows.get(sheet_name, [])
fig, ax = plt.subplots(figsize=(15, 8))
ax.set_xlim(-1.1, 1.1)
ax.set_ylim(-1.1, 1.1)
ax.set_aspect('equal')

# Add circles below arrows (zorder=1) with associated colors
for i, tab_name in enumerate(sheet_names):
color = get_color(tab_name)
ax.add_patch(plt.Circle((x[i], y[i]), 0.05, color=color, zorder=1))
ax.annotate(tab_name, (x[i], y[i]), ha='center', va='center', zorder=1)

# Add arrows for the current tab group
for arrow in arrows:
start, end, force, arc3_rad, color_outgoing = arrow
fleche = ax.annotate("", xy=end, xytext=start, arrowprops=dict(arrowstyle='simple',
color=color_outgoing, lw=scale*force, connectionstyle=f"arc3,rad={arc3_rad}",
shrinkA=0, shrinkB=arrow_circle_gap))
fleche.set_zorder(0)

# Figure settings
ax.axis('off')

# Add legend to the rectangle
legend_texts = []
# Use the sorted() function with the key parameter to sort based on the first element of
each sublist
arrows = sorted(arrows, key=lambda x: x[2], reverse=True)
for arrow in arrows[:max_arrows]:
start, end, force, _, _ = arrow
start_sheet_name = None
end_sheet_name = None

# Find the starting tab name associated with the "start" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == start:
start_sheet_name = sheet_name
break

# Find the ending tab name associated with the "end" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == end:
```

```
end_sheet_name = sheet_name
break

# Handle the case where the tab name is not found for the start or end coordinates
if start_sheet_name is None:
start_sheet_name = "Unknown"
if end_sheet_name is None:
end_sheet_name = "Unknown"

link_text = f"Link {start_sheet_name} to {end_sheet_name:<4}: F = {force:.2f}"
legend_texts.append(link_text)

# Add rectangle to the right of the figure
rect_width = 0.147
rect_height = (0.08 + 0.041 * (len(legend_texts) - 1)) * (-1)
rect_left = 0.705 # Adjust the value according to the desired location
rect_bottom = 0.75
rect = patches.Rectangle((rect_left, rect_bottom), rect_width, rect_height,
transform=fig.transFigure, facecolor='white', edgecolor='black', linewidth=2.0, zorder=-1)
fig.patches.append(rect) # Add the rectangle directly to the figure

# Adjust margins for text
rect_margin = 0.00
text_margin = 0.34 # Adjust this value as needed

trans = transforms.blended_transform_factory(ax.transAxes, fig.transFigure)
for i, text in enumerate(legend_texts):
text_y = rect_bottom - (i + 1) * (0.5 - 2 * rect_margin) / max_arrows
ax.text(rect_left + rect_width + text_margin, text_y, text, ha='left', va='center',
fontsize=10, transform=trans)

plt.subplots_adjust(right=0.75) # Adjust the position of the figure to make room for the
legend

plt.show()

## Display by Subclass - All Arrows

# List of tab names
sheet_names = wb.sheetnames

# Dictionary to store arrows by tab group
grouped_arrows = {}

# Searching for arrows originating from current tabs
```

```
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 array is empty
if ws['P2'].value == "Empty":
continue # Ignore empty arrays

# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Search the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
other_index = sheet_names.index(class_b)

# Calculate the arc3_rad value proportional to the number of circles separating the two
connected circles
arc3_rad = calculate_arc3_rad(index, other_index, len(sheet_names), scale)

# Get arrow color based on current tab
color_outgoing = get_color(sheet_name)
color_incoming = get_color(class_b)

# Add arrow to tab groups for arrows originating from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append(((x[index], y[index]), (x[other_index],
y[other_index]), Link_Strength[j], arc3_rad, color_outgoing))

# Searching for tabs that have the current tab in their "Classe b" column
for k, other_sheet_name in enumerate(sheet_names):
if other_sheet_name == class_b:
```

```
# Add arrows for tabs that arrive at current tabs
if class_b not in grouped_arrows:
grouped_arrows[class_b] = []
grouped_arrows[class_b].append(((x[index], y[index]), (x[other_index], y[other_index]),
Link_Strength[j], arc3_rad, color_incoming))

# Create figures for each tab group
for sheet_name in sheet_names:
arrows = grouped_arrows.get(sheet_name, []) # Use get() to handle the case where
sheet_name is not present in the dictionary
fig, ax = plt.subplots(figsize=(8, 8))
ax.set_xlim(-1.1, 1.1)
ax.set_ylim(-1.1, 1.1)
ax.set_aspect('equal')

# Add circles below arrows (zorder=1) with associated colors
for i, tab_name in enumerate(sheet_names):
color = get_color(tab_name)
ax.add_patch(plt.Circle((x[i], y[i]), 0.05, color=color, zorder=1))
ax.annotate(tab_name, (x[i], y[i]), ha='center', va='center', zorder=1)

# Add arrows for the current tab group
for arrow in arrows:
start, end, force, arc3_rad, color_outgoing = arrow
fleche = ax.annotate("", xy=end, xytext=start, arrowprops=dict(arrowstyle='simple',
color=color_outgoing, lw=scale*force, connectionstyle=f"arc3,rad={arc3_rad}",
shrinkA=0, shrinkB=arrow_circle_gap))
fleche.set_zorder(0)

# Figure settings
ax.axis('off')

plt.show()

## Display by Subclass - All Arrows with Legend

# Dictionary to store arrows by tab group
grouped_arrows = {}

# Searching for arrows originating from current tabs
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 array is empty
if ws['P2'].value == "Empty":
```

```
continue # Ignore empty arrays

# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Search the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
other_index = sheet_names.index(class_b)

# Calculate the arc3_rad value proportional to the number of circles separating the two
connected circles
arc3_rad = calculate_arc3_rad(index, other_index, len(sheet_names), scale)

# Get arrow color based on current tab
color_outgoing = get_color(sheet_name)
color_incoming = get_color(class_b)

# Add arrow to tab groups for arrows originating from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append(((x[index], y[index]), (x[other_index],
y[other_index]), Link_Strength[j], arc3_rad, color_outgoing))

# Searching for tabs that have the current tab in their "Classe b" column
for k, other_sheet_name in enumerate(sheet_names):
if other_sheet_name == class_b:
# Add arrows for tabs that arrive at current tabs
if class_b not in grouped_arrows:
grouped_arrows[class_b] = []
grouped_arrows[class_b].append(((x[index], y[index]), (x[other_index], y[other_index]),
Link_Strength[j], arc3_rad, color_incoming))
```

```
# Create figures for each tab group
for sheet_name in sheet_names:
arrows = grouped_arrows.get(sheet_name, [])
fig, ax = plt.subplots(figsize=(15, 8))
ax.set_xlim(-1.1, 1.1)
ax.set_ylim(-1.1, 1.1)
ax.set_aspect('equal')

# Add circles below arrows (zorder=1) with associated colors
for i, tab_name in enumerate(sheet_names):
color = get_color(tab_name)
ax.add_patch(plt.Circle((x[i], y[i]), 0.05, color=color, zorder=1))
ax.annotate(tab_name, (x[i], y[i]), ha='center', va='center', zorder=1)

# Add arrows for the current tab group
for arrow in arrows:
start, end, force, arc3_rad, color_outgoing = arrow
fleche = ax.annotate("", xy=end, xytext=start, arrowprops=dict(arrowstyle='simple',
color=color_outgoing, lw=scale*force, connectionstyle=f"arc3,rad={arc3_rad}",
shrinkA=0, shrinkB=arrow_circle_gap))
fleche.set_zorder(0)

# Figure settings
ax.axis('off')

# Add legend to the rectangle
legend_texts = []
# Use the sorted() function with the key parameter to sort based on the first element of
each sublist
arrows = sorted(arrows, key=lambda x: x[2], reverse=True)
for arrow in arrows[:max_arrows]:
start, end, force, _, _ = arrow
start_sheet_name = None
end_sheet_name = None

# Find the starting tab name associated with the "start" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == start:
start_sheet_name = sheet_name
break

# Find the ending tab name associated with the "end" coordinate
for sheet_name, coord in sheet_coordinates.items():
if coord == end:
```

```
end_sheet_name = sheet_name
break

# Handle the case where the tab name is not found for the start or end coordinates
if start_sheet_name is None:
start_sheet_name = "Unknown"
if end_sheet_name is None:
end_sheet_name = "Unknown"

link_text = f"Link {start_sheet_name} to {end_sheet_name:<4}: F = {force:.2f}"
legend_texts.append(link_text)

# Add rectangle to the right of the figure
rect_width = 0.147
rect_height = (0.08 + 0.041 * (len(legend_texts) - 1)) * (-1)
rect_left = 0.705 # Adjust the value according to the desired location
rect_bottom = 0.75
rect = patches.Rectangle((rect_left, rect_bottom), rect_width, rect_height,
transform=fig.transFigure, facecolor='white', edgecolor='black', linewidth=2.0, zorder=-1)
fig.patches.append(rect) # Add the rectangle directly to the figure

# Adjust margins for text
rect_margin = 0.00
text_margin = 0.34 # Adjust this value as needed

trans = transforms.blended_transform_factory(ax.transAxes, fig.transFigure)
for i, text in enumerate(legend_texts):
text_y = rect_bottom - (i + 1) * (0.5 - 2 * rect_margin) / max_arrows
ax.text(rect_left + rect_width + text_margin, text_y, text, ha='left', va='center',
fontsize=10, transform=trans)

plt.subplots_adjust(right=0.75) # Adjust the position of the figure to make room for the
legend

plt.show()
```

Algorithme-A 2.a-3 Global overview of interlinkages

```
## Function definition

# Generate a color palette based on the leading digits of sheet names
def get_color(name):
```

```
colors = {
'1': '#E32322',
'2': '#EA601F',
'3': '#FCC509',
'4': '#8CBA26',
'5': '#0595BA',
'6': '#376BFF',
'7': '#AB57FF',
'8': '#FD4D98',
}

# Additional colors for digits > 8
extra_colors = ['#FF6633', '#33CC33', '#FF3300', '#FF66CC', '#3399FF', '#9933CC',
'#FF9933', '#99CC33']

# Convert the name to a string
name_str = str(name)

first_digit = name_str[0]
if first_digit.isdigit():
if first_digit in colors:
return colors[first_digit]
else:
# Use an additional color if the digit goes beyond 8
color_index = int(first_digit) % len(extra_colors)
return extra_colors[color_index]
else:
return 'cornflowerblue'

## Code initialization

sheet_names = wb.sheetnames

# Dictionary to store arrows by tab group
grouped_arrows = {}


# Search for arrows departing from current tabs
for i, sheet_name in enumerate(sheet_names):
ws = wb[sheet_name]

# Check if tab2 is empty
if ws['P2'].value == "Empty":
continue # Ignore empty tables
```

```
# Retrieve values of class_b and Link_Strength from columns P and Q from row 2 until an
empty cell
classes_b = []
Link_Strength = []
row_num = 2
while True:
class_b = ws.cell(row=row_num, column=16).value
indiv_strenght = ws.cell(row=row_num, column=17).value
if class_b is None:
break
classes_b.append(class_b)
Link_Strength.append(indiv_strenght)
row_num += 1

# Find the index of the current tab in the list of tab names
index = sheet_names.index(sheet_name)

# Find the index of each associated tab in the list of tab names
for j, class_b in enumerate(classes_b):
autre_index = sheet_names.index(class_b)

# Get the color of the arrow based on the current tab
color_outgoing = get_color(sheet_name)

# Add the arrow to tab groups for arrows departing from current tabs
if sheet_name not in grouped_arrows:
grouped_arrows[sheet_name] = []
grouped_arrows[sheet_name].append((Link_Strength[j],color_outgoing))

# Search for tabs that have the current tab in their "Classe b" column
for k, other_sheet_name in enumerate(sheet_names):
if other_sheet_name == class_b:
# Add arrows for tabs arriving at current tabs
if class_b not in grouped_arrows:
grouped_arrows[class_b] = []
grouped_arrows[class_b].append((Link_Strength[j], color_outgoing))


## Overview
somme = 0
tab_links = []
nb_links = []

for tab in grouped_arrows:
tab_links.append((tab, len(grouped_arrows[tab])))
```

```
nb_links.append(len(grouped_arrows[tab]))
somme = somme + (len(grouped_arrows[tab]))

if len(grouped_arrows[tab]) == 0:
print("Pas de lien partant du tab", tab)

print("Total number of links =", somme)
print(")
print("Mean number of links per class =", round(somme / 33, 2))
print(")
for i in range(len(nb_links)):
if tab_links[i][1] == max(nb_links):
print("Class", tab_links[i][0], "has the highest number of links with", max(nb_links))
print(")
for i in range(len(nb_links)):
if tab_links[i][1] == min(nb_links):
print("Class", tab_links[i][0], "has the lowest number of links with", min(nb_links))

## Class diagramm

import matplotlib.pyplot as plt

# Création d'un dictionnaire pour stocker les sommes des entiers par premier caractère
sum_by_char = {}
for item in tab_links:
char = item[0][0] # Premier caractère de la string
value = item[1]
if char in sum_by_char:
sum_by_char[char] += value
else:
sum_by_char[char] = value

# Conversion du dictionnaire en liste de tuples (premier caractère, somme des entiers)
total_class_links = list(sum_by_char.items())

# Tri de la liste total_class_links par ordre croissant du premier caractère
total_class_links_sorted = sorted(total_class_links, key=lambda x: x[0])

# Séparation des données triées en deux listes (premiers caractères et sommes des entiers)
labels, values = zip(*total_class_links_sorted)

# Création du diagramme en bâtons avec les couleurs
colors = [get_color(label) for label in labels]
plt.bar(labels, values, color=colors)
```

```
# Ajout des légendes aux bâtons
for i, value in enumerate(values):
plt.text(i, value, str(value), ha='center', va='bottom')

# Réglages du graphique
plt.xlabel("Class number")
plt.ylabel("Total number of links per class")
plt.title("")
plt.xticks(rotation=45)
plt.tight_layout()

# Affichage du graphique
plt.show()


## Subclass diagram

import matplotlib.pyplot as plt


# Tri de la liste de tuples par ordre croissant des entiers
data_sorted = sorted(tab_links, key=lambda x: x[1])

# Séparation des données triées en deux liste s (chaînes et entiers)
labels, values = zip(*data_sorted)

# Création du diagramme en bâtons
colors = [get_color(label) for label in labels]
plt.bar(labels, values, color=colors)

# Ajout des légendes aux bâtons
for i, value in enumerate(values):
plt.text(i, value, str(value), ha='center', va='bottom')

# Réglages du graphique
plt.xlabel("Subclass number")
plt.ylabel("Total number of links per subclass")
plt.title("")
plt.xticks(rotation=45)
plt.tight_layout()

# Affichage du graphique
plt.show()
```

ANNEXE 2.b

FURTHER ELUCIDATIONS ABOUT THE OPERATION AND CALCULATION OF χ^2

The χ^2 test is a statistical tool used to assess the links between categorical variables. It aims to determine whether the observed frequencies differ significantly from the theoretical frequencies under the hypothesis of independence between these variables. In other words, it measures the distance between them. For the purposes of this article, the χ^2 calculation takes two different forms. The first corresponds to its application in the context of the HCA and is used to evaluate the distance between two groups of text segments. In the second case, it is used to evaluate the dependence of a form on a class following a HCA. The next two sections briefly explain how they are used.

Case of the χ^2 used for the HCA

To illustrate the application of this statistical test to the case of HCA in IRaMuTeQ, let us consider a corpus composed of five text segments S1, S2, S3, S4, and S5. These are based solely on seven active forms described in Tableau-A 2.b-1, which respectively code the absence or presence of these forms in each of the text segments with a 0 or a 1.

Tableau-A 2.b-1 Sample text segments for χ^2 calculation

	Forms						
Segment	energy	renewable	community	oil	housing	electricity	heat
S1	0	1	0	1	1	1	1
S2	1	0	0	0	0	1	0
S3	0	0	1	0	1	1	0
S4	0	1	0	1	1	0	1
S5	1	0	1	0	1	1	0

The aim of the HCA is to group the text segments into the two most different groups from all possible configurations. To measure this difference, the χ^2 of each pair is evaluated. The lower the χ², the more similar the two groupings. Conversely, the greater the χ², the more they differ. The calculation of the χ² of a pair can be defined by equation (A 2.b-3), although the mathematical formula actually used by IRaMuTeQ is not available in the software documentation. It corresponds to the sum of the distances d_{ij} between the observed frequencies O_{ij} and the theoretical frequencies E_{ij} under the assumption of independence.

$$\chi^2 = \sum_{i,j} d_{ij} = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \qquad \text{(A 2.b-3)}$$

Firstly, the observed frequencies of occurrence O_{ij} are calculated by summing the rows in Tableau-A 2.b-1 corresponding to the configuration studied and adding them to a contingency table (Tableau-A 2.b-2). In this example, the pair of segment groups studied corresponds to the grouping of segments S1 and S4 on the one hand and segments S2, S3 and S5 on the other.

Tableau-A 2.b-2 Observed frequencies of the seven active forms for a pair of segment groups

	Forms							
Group of segments	energy	renewable	community	oil	housing	electricity	heat	Total
S1+S4	$O_{11} = 0$	$O_{12} = 2$	$O_{13} = 0$	$O_{14} = 2$	$O_{15} = 2$	$O_{16} = 1$	$O_{17} = 2$	9
S2+S3+S5	$O_{21} = 2$	$O_{22} = 0$	$O_{23} = 2$	$O_{24} = 0$	$O_{25} = 2$	$O_{26} = 3$	$O_{27} = 0$	9
Total	2	2	2	2	4	4	2	18

Next, the theoretical frequencies E_{ij} described by equation (A 2.b-4) are calculated (Tableau-A 2.b-3).

$$E_{ij} = \frac{\sum_i O_{ij} \cdot \sum_j O_{ij}}{\sum_{i,j} O_{ij}} \qquad \text{(A 2.b-4)}$$

Tableau-A 2.b-3 Calculated theoretical frequencies of the seven active forms for a pair of segments groups

Group of segments	Forms							Total
	energy	renewable	community	oil	housing	electricity	heat	
S1+S4	$E_{11} = 1$	$E_{12} = 1$	$E_{13} = 1$	$E_{14} = 1$	$E_{15} = 2$	$E_{16} = 2$	$E_{17} = 1$	9
S2+S3+S5	$E_{21} = 1$	$E_{22} = 1$	$E_{23} = 1$	$E_{24} = 1$	$E_{25} = 1$	$E_{26} = 1$	$E_{27} = 1$	9
Total	2	2	2	2	4	4	2	18

Thus, the distances d_{ij} between the two frequencies are evaluated (Tableau-A 2.b-4) and then summed, resulting in the χ² value (Tableau-A 2.b-5).

Tableau-A 2.b-4 Distances between observed and theoretical frequencies for a pair of segment groups

Group of segments	Forms						
	energy	renewable	community	oil	housing	electricity	heat
S1+S4	$d_{11} = 1$	$d_{12} = 1$	$d_{13} = 1$	$d_{14} = 1$	$d_{15} = 0$	$d_{16} = 0{,}5$	$d_{17} = 1$
S2+S3+S5	$d_{21} = 1$	$d_{22} = 1$	$d_{23} = 1$	$d_{24} = 1$	$d_{25} = 0$	$d_{26} = 0{,}5$	$d_{27} = 1$

As indicated by equation (A 2.b-3), the sum of all the terms from Tableau-A 2.b-4 gives the value of χ² for the pair of segments studied. Among the sample of possible groupings presented by Tableau-A 2.b-5, the most likely to be retained corresponds to the pair S1+S4/ S2+S3+S5 because it has the highest χ² value, while the pair S1+S5/S2+S3+S4 is identical, which implies that the associated χ² is zero.

Tableau-A 2.b-5 Sample of possible splits and associated χ^2 values

Group of segments	energy	renewable	community	oil	housing	electricity	heat	χ^2 value
S1+S2	1	1	0	1	1	2	1	2,2
S3+S4+S5	1	1	2	1	3	2	1	
S1+S3	0	1	1	1	2	2	1	1,8
S2+S4+S5	2	1	1	1	2	2	1	
S1+S4	0	2	0	2	2	1	2	11
S2+S3+S5	2	0	2	0	2	3	0	
S1+S5	1	1	1	1	2	2	1	0
S2+S3+S4	1	1	1	1	2	2	1	

The case of the χ^2 used to evaluate the dependence of a form on a class

To illustrate the application of the test for evaluating the dependency of a form on a class, we consider that the result of a previous HCA resulted in five classes C1, C2, C3, C4 and C5. The same seven active forms are used for the example. Their numbers are shown by class in Tableau-A 2.b-6. Once again, it should be noted that the mathematical formula applied here does not correspond to that used by the IRaMuTeQ software. Moreover, the specific case of this analysis shows negative χ^2 values with the software, which is impossible here with the formula taken into consideration.

Tableau-A 2.b-6 Observed frequencies of the seven active forms in the five classes

Classes	energy	renewable	community	oil	housing	electricity	heat	Total
C1	12	5	6	7	8	1	4	12
C2	14	5	8	62	8	9	56	14
C3	88	124	1	0	2	4	10	88
C4	12	14	8	7	2	1	8	12
C5	4	0	56	0	62	38	0	4
Total	130	148	79	76	82	53	78	130

Next, the theoretical frequencies E_{ij} are calculated, in the same way as for the previous example, using equation (A 2.b-4). They are shown in Tableau-A 2.b-7.

Tableau-A 2.b-7 Calculated theoretical frequencies of the seven active forms in the five classes

Classes	Forms							Total
	energy	renewable	community	oil	housing	electricity	heat	
C1	8,65	9,85	5,26	5,06	5,46	3,53	5,19	12
C2	32,60	37,11	19,81	19,06	20,56	13,29	19,56	14
C3	46,08	52,46	28,00	26,94	29,07	18,79	27,65	88
C4	10,46	11,91	6,36	6,12	6,60	4,27	6,28	12
C5	32,20	36,66	19,57	18,82	20,31	13,13	19,32	4
Total	130	148	79	76	82	53	78	130

Finally, the distances d_{ij} are calculated in the same way as for the previous example, as shown in equation (A 2.b-3). This distance corresponds to the χ^2 mentioned in the analysis derived from the HCAs concerning the links between classes and shapes. Tableau-A 2.b-8 illustrates the strength of the dependency between a class and a shape. More precisely, the higher the value of the distance, the stronger the link, and vice versa.

Tableau-A 2.b-8 χ^2 values of the seven active forms in the five classes

	Forms						
Classes	energy	renewable	community	oil	housing	electricity	heat
C1	1,29	2,39	0,10	0,74	1,18	1,81	0,27
C2	10,61	27,79	7,04	96,75	7,68	1,39	67,88
C3	38,13	97,54	26,04	26,94	25,21	11,64	11,27
C4	0,23	0,37	0,42	0,13	3,21	2,50	0,47
C5	24,70	36,66	67,84	18,82	85,58	47,13	19,32

ANNEXE 2.c

BANK OF INDICATOR

Tableau-A 2.c-1 Indicators for technical dimension

Topic	Indicator	Set n°
Clean or sustainable energy	Renewable energy share in energy and electricity	4,5,13,9,14,15, 18
	Primary production of renewable energy	15
	Renewable energy resource	16
	Non-carbon energy share in energy and electricity	5,9,10
	Share of capacity of renewable energy per total electricity generation	9,15,16
	Electrical capacity—Hydro, Wind, Solar	15
	RES electricity %	3
	RES per fossil fuel electricity production	3
	RES thermal %	3
	The share of renewables in heat production	6
Energy efficiency	Commercial Energy Efficiency	10
	Industrial Energy Efficiency	10
	Cooking/heating energy conversion efficiency	4
	Energy saved in buildings	6
	Household Energy Efficiency	10
	Amount of electricity generated by one unit of energy resources mix in Low Heating Value (LHV)	12
	Load factor for gross electric capacities	18
	Efficiency of energy conversion and distribution	4,5,9,13,14,16,18
	Ratio of final over primary consumption	18
	Subterranean share of transmission and distribution system	18
	Electric Power Transmission Line Mileage	10
	Overall system Conversion Efficiency	1
	Savings of primary energy supply	6
	The share of CHP[(1)] in electricity production	6
	Motor Vehicle Average MPG	10
	Vehicle-Miles Traveled per GDP	10
	Average age of cars and ships	18

Topic	Indicator	Set n°
Overall use and production	Total primary energy supply	18
	Total energy consumption (primary of final) by type, per capita, over GDP, or by sector	18
	Frequency of electric power grid	18
	Fuel shares in energy and electricity	5,11
	Diversity-index for energy consumption by sector	18
	Total gross electricity generation	15
	Total domestic generation and share by type	18
	Electrical capacity - Combustible fuels	15
	Electricity production from coal and oil	16
	Share of 'dirty fuels' in residential energy consumption	1
Transportation	Number of fast-charging spots and other eco-friendly multi-fuel stations	18
	Share of passenger cars by fuel type	18
	Energy consumption for transportation by fuel	18
	Proportion of renewable fuels in total fuel for ships	18
	The share of renewables in fuel used in transport	6
	Transportation Non-Petroleum Fuel Use	10
	Number of planes that use land connected electrical charging	18
Reliability / Availability	Electricity Capacity Diversity	10
	Electricity Capacity Margins	10
	Frequency and duration of blackouts	18
	Period when demand reaches 85% of total capacity of electricity supply system	12
(1) Combined heat and power		

Tableau-A 2.c-2 Indicators for technico-economic dimension

Topic	Indicator	Set n°
Energy cost	Crude Oil Price Volatility	10
	Crude Oil Prices	10
	End-use energy prices by fuel and by sector	5
	Retail price of gasoline/petrol	13,14
	Average levelized cost of electricity	18
	Proportion of energy use covered by long-term contracts	18

Topic	Indicator	Set n°
Energy intensity	Energy use per unit of GDP	1,5,9,13,14
	Share of productive use of energy	1
	Total primary energy intensity	9,10
	Agriculture Energy Intensity	5,9,18
	Commercial Energy Intensity	5,9,18
	Industrial Energy Intensity	5,9,18
	Transportation Energy Intensity (TEI)	5,9,18
	Petroleum Intensity	10
	CO_2 emission per GDP	9, 10
Energy security - Dependency	Overall Self Sufficiency	1,13,14
	Net Energy Import Dependency (NEID)	4,5,9,11
	Proportion of domestic energy sources in TPES	18
	Proportion of imported energy in TPES	18
	Share of foreigner supplies of energy resources in the electricity generation portfolio (coal, natural gas, Heavy Fuel Oil and nuclear)	12
	Variety of energy resources of electricity generation portfolio, measured by the Shannon–Weiner index	12
	Diversity-index for energy supply by type	18
	Net import dependence for gas, oil, or coal	11
	Foreigner reliance on fossil fuel resources	12
	Share of imports coming from politically unstable countries	18
	Degree of transportation risk management	18
	Political risk index of the supplier countries	11
Energy security - Imports	Total net positive imports of gas, oil, or coal over all suppliers	11
	Net positive imports of gas, oil, or coal for each supplier country	11
	Oil & Natural Gas Import Expenditures	10
	Oil & Natural Gas Import Expenditures per dollar of GDP	10
	Annual value of energy exports	13,14
	Fungibility of imports of gas, oil, or coal for each supplier country	11
	Security of U.S. Natural Gas Imports	10
	Security of U.S. Petroleum Imports	10
	Depletion coefficient of local energy resources	1
	Share of depletable (nonrenewable) energies in total primary energy supply (TPES)	1
	Reserves-to-production ratio	5
	Reserve Production ratio (RPR) Crude oil	9

Topic	Indicator	Set n°
Energy security - Reserves	Reserve Production ratio (RPR) Natural Gas	9
	Reserve Production ration (RPR) Coal	9
	Petroleum Stock Levels	10
	Stocks of critical fuels per corresponding fuel consumption	5, 13, 14
	Average reserve to production ratio for the three primary energy fuels (coal, natural gas, and oil)	13,14
	Dynamic reserve/production ratio	18
	Critical surplus	18
Global supply	Security of World Coal Production	10
	Security of World Coal Reserves	10
	Security of World Natural Gas Production	10
	Security of World Natural Gas Reserves	10
	Security of World Oil Production	10
	Security of World Oil Reserves	10
	World Oil Refinery Utilisation	10

Tableau-A 2.c-3 Indicators for technico-social dimension

Topic	Indicator	Set n°
Access to modern or clean energy	Electricity access	17
	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy	4,5,9
	Share of population with high quality connections to the electricity grid	13,14
	Households dependent on traditional fuels	4,13,14
	Per capita consumption of clean energies in the residential sector	1
	Modern cooking fuel	17
Energy equity	Disparity in clean energy distribution	4
	Disparity in electricity distribution	4
	Household energy use for each income group and corresponding fuel mix	5
	Energy Expenditures per Household	10
	Energy price volatility	18
	Share of household income spent on fuel and electricity	4,5,18
	Share of income pay to electricity	9
	Retail Electricity Prices	10
	Stability of electricity prices	13,14

Topic	Indicator	Set n°
	Entertainment/education appliance ownership	17
	Household appliance ownership	17
	Telecommunication means	17
Use and production patterns	Energy use per capita	3,5,9,10, 13, 14
	Electricity per capita	4,5,9,16
	Fossil-fuel consumption per inhabitant	3
	RES production per inhabitant	3
	Household energy per capita	9
	Household electricity per capita	9
	Household energy intensities	5
	Residential energy per household	9
	Per capita consumption of commercial energies	1
	Share of different forms of transportation chosen	18
	Share of passenger cars by fuel type	18
	Energy consumption for transportation by fuel	18

Tableau-A 2.c-4 Indicators for socio-economic and socio-environmental dimensions

Topic	Indicator	Set n°
Health & safety	Share of population with access to improved water	13,14
	Accident fatalities per energy produced by fuel chain	5
	Impact of household air pollution (HAP) from energy systems	4
	Indoor pollution	17
Socio-demographic data	Income inequality	1
	GDP per inhabitant	3
	GDP per capita	15
	Affordability of financial services	15
	Population density	3
	Ratio of local residents to peak season tourists %	3
	Science & Engineering Degrees	10
	Public participation in energy-related policymaking	18
	Socially beneficial initiatives	18

Tableau-A 2.c-5 Indicators for technico-environmental dimension

Topic	Indicator	Set n°
GHG emissions	GHG emissions from energy production and use per capita and per unit of GDP	4,5,10,13, 14,15,18
	Carbon intensity	1
	Total CO2 eq. emissions per kWh of generated electricity	12
	CO_2 emissions from fuel combustion per population	13
	CO_2 emission per capita (from fossil fuels)	9
	Emission factor of fossil fuels	18
	Amount of carbon sequestration by energy industry	18
Pollution and land alteration	Net emissions from energy production and utilisation for SO_2, H_2S, and $PM_{2,5}$ per capita, over GDP, by sector, or by TPES	18
	Air pollutant emissions from energy systems	5
	Per capita sulfur dioxide emissions	13,14
	Total SO_{2e} emissions per kW h_e of generated electricity	12
	Total PM_{10e} emissions per kW h_e of generated electricity	12
	Ambient concentrations of air pollutants in urban areas	5, 18
	Rate of deforestation attributed to energy use	5
	Annual rate of change in forest area	4
	Total impact area of power plants	18
	Forest area as percent of land area	13,14
	Contaminant discharges in liquid effluents from energy systems including oil discharges	5
	Soil area where acidification exceeds critical load	5
	Quality of the natural environment	15
Solid waste	Amount of radioactive waste produced per kWh of generated electricity	12
	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste	5
	Ratio of solid radioactive waste to units of energy produced	5
	Ratio of solid waste generation to units of energy produced	5
	Ratio of solid waste properly disposed of to total generated solid waste	5

Tableau-A 2.c-6 Indicators for institutional and economic dimensions

Topic	Indicator	Set n°
	Debt to GDP	16
	Economic growth rate	15, 16

Topic	Indicator	Set n°
Economics	Inflation rate	15
	Unemployment rate	16
	Job creation	18
	Interest rate	16
	Currency movement	16
	Control of corruption	16
	Enforcement of environmental regulation	15
Governance & policy	Tax revenue of carbon tax and fossil fuels	18
	Government Effectiveness	15, 16
	Political Stability and Absence of Violence/Terrorism	15, 16
	Regulatory Quality	15, 16
	Renewable energy policies	16
	Government revenue from energy sales	18
	Stringency of environmental regulation	15
	Transparency of government policymaking	15, 18
	Worldwide governance rating	13,14
Investments & expenditures	Energy Expenditures per dollar of GDP	10
	Energy Expenditure Volatility	10
	Cost of energy subsidies per person	13,14
	Government expenditures on research and development compared to all expenditures	13,14
	Government investments in energy infrastructure development	18
	Government expenditure on fossil fuel subsidies	18
	Investment in the energy sector	18
	Total R&D expenditure within the energy sector	18
	Company spending on R&D	15
	Industrial Energy R&D Expenditures	10
	Federal Energy & Science R&D Expenditures	10
	Foreign direct investment (FDI) annual growth rate, net inflows	16
	Foreign direct investment (FDI) & technology transfer	18
Other data	Availability of latest technologies	15
	Capacity for innovation	15
	University-industry collaboration in R&D	15, 18
	Information	13,14
	Number of patents in the energy sector	18

ANNEXE 4.a

CORPUS CONSTRUCTION

The first exhaustive list of keywords has been classified into five categories: general concepts (1st), energy sources and carriers (2nd), energy production (3rd), energy uses (4th) and energy system and environment actors (5th) (Tableau-A 4.a-1). In order to gain in efficiency and time, it was refined - and therefore reduced - before being used. To this end, tests were carried out on a sample of the corpus: nine issues of *Taqralik Magasine*, e.g. around 340 pages, and five issues of *Nunatsiaq News*, e.g. 96 pages. Among these issues, 794 keywords were manually detected. On average, each keyword appears 17 times, but the median is lower: seven times. This reflects a disparity in appearance frequencies, which range from simple to hundredfold depending on the keyword (Figure-A 4.a-1). Except for keywords in the 5th category, those appearing seven times (median) or less are discarded as being too ineffective, thus halving the list of keywords. The exception is "Régie de l'énergie", which is also discarded as it will logically be associated with the other keyword "energy".

Tableau-A 4.a-1 English[(1)] version of the initial unrefined list of keywords

Category	Keyword	Meaning
1. General concepts	Energy	In terms of physical quantity
	Transition	In the context of energy/ecological transition
	Sustainable	As part of sustainable development
	Environment	In the context of the natural environment: biodiversity, landscapes, ecosystems, water, soil, atmosphere, etc.
	Nature	Related ton environment
	Power	Related to energy supply/production.
	Supply	Related to energy availability and production
	Grid	As part of an electricity or heat network
	Climate Change	As the phenomenon described by the IPCC
	Emissions	As part of greenhouse gas emissions
	Greenhouse gas / GHG	E.g. : carbon dioxide, methane, nitrous oxide, etc.
	Carbon	In the physical sense of the atom present in fossil fuels and greenhouse gases

Category	Keyword	Meaning
2. Energy sources and carriers	Fuel	E.g. : fuel oil, petrol, heating oil, etc.
	Fossil	In the context of fossil fuels : oil, natural gas and coal
	Gas / Gaz	As natural gas or biogas
	Diesel / Gasoline	As the fossil fuel
	Oil / Petrol-eum	As the fossil fuel
	Heat	As the form of energy
	Electricity	As the energy carrier
3. Energy production	Wind turbine / Wind power	As a means of generating electricity
	Solar / photovoltaic panel	As a means of generating electricity
	Thermal	Related to heat
	Geothermal	Related to the heat stored and released in soils
	Plant	As a power generation infrastructure
	Tidal	As a means of generating electricity
	Biomass	As the living matter used as a fuel
	Hydroelectricity	As a means of generating electricity
4. Energy uses	Greenhouse	As the means of agricultural production
	Transport	In the context of transport of goods and people
	Car	As a means of transport
	Truck	As a means of transport
	Boat	As a means of transport
	Plane / Airplane	As a means of transport
	Airport	In the field of transport infrastructure
	Flight	In the context of transport by plane
	Cargo	In the context of transport of goods
	Boilet	As a heating system
	Furnace	As a heating system
	Oven	As a cooking appliance
	Cook	As the action of cooking food

Category	Keyword	Meaning
5. Energy system and environment actors	Hydro-Québec	State-owned electricity producer and supplier
	Tugliq	Private company carrying out renewable energy projects in northern Canada
	Tarquti	Inuit company affiliated with Makivik and FCNQ(2)
	Régie de l'énergie	Economic regulator for the energy sector
	Air Inuit	Canadian airline serving mainly Nunavik
	Canadian North / First Air	Canadian airline serving Canada's northern territories
(1) Tableau-A 4.a-3 shows the French-language equivalents used to construct the corpus, since it is French-speaking.		
(2) Fédérations des coopératives du Nouveau-Québec: group of Inuit firms in Nunavik		

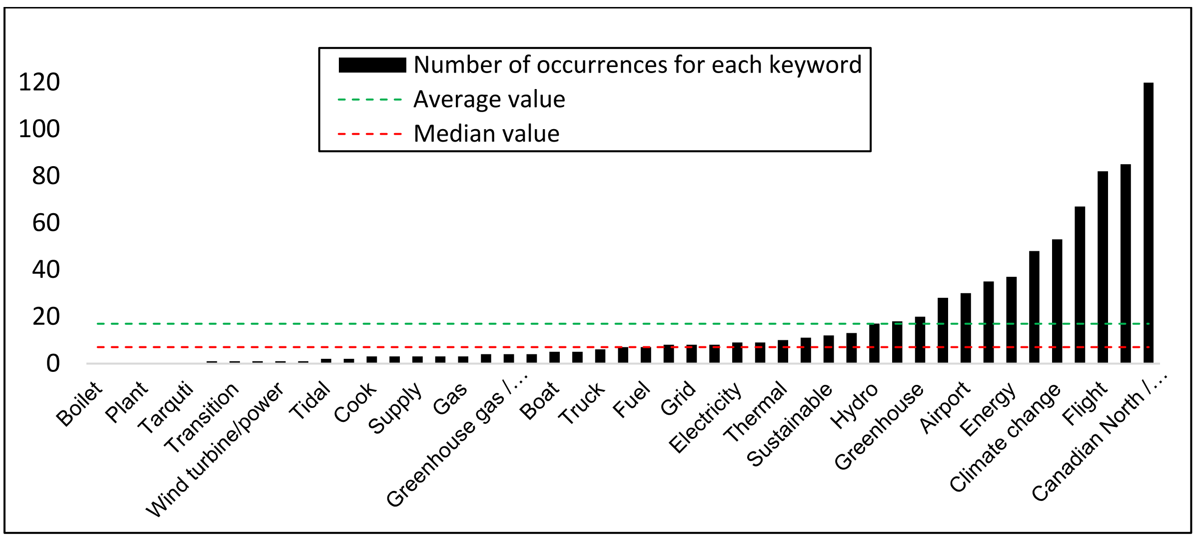


Figure-A 4.a-1 Number of occurrences per keyword in the sample studied

Next, an analysis of the correlation between the different keywords is carried out. The aim is to eliminate those keywords which generally appear together in the same articles to talk about the same subjects, except for those in the 5th category which are deemed irreplaceable. A correlation coefficient is calculated for each pair of keywords (Tableau-A 4.a-2). If a coefficient is close to 1, it must also be manually checked that the two keywords concerned appear in the same newspaper article and not in separate articles within the same issue. In the first case, the correlation is validated and the one least likely to encompass the other in the general case must be eliminated. This choice is left to the author's understanding and interpretation. In the second case, the correlation is not taken into account. Finally, a list of 19 keywords is retained for corpus construction. It is defined more precisely in Tableau-A 4.a-3 alongside further details and explanations of how this second refinement stage was carried out.

Tableau-A 4.a-2 Correlation of keyword occurrences in the sample studied

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		Energy	Sustainable	Environment	Power	Grid	Climate c.	Greenhouse	Emissions	Diesel	Oil / Petroleum	Electricity	Transport	Plane	Airport	Flight	Cargo	Solar panel	Hydroelectricity	Hydro-Québec
A	Energy		-0.14	-0.08	0.92	0.99	-0.06	-0.09	0.74	0.92	-0.09	0.90	-0.17	0.45	-0.03	-0.06	-0.16	0.93	0.05	
B	Sustainable			0.62	-0.26	-0.22	0.24	0.76	-0.30	-0.28	0.68	-0.12	0.51	0.27	0.21	0.66	0.41	-0.25	0.09	
C	Environment				-0.02	-0.11	0.65	0.69	0.08	-0.06	0.63	0.12	0.52	0.41	0.12	0.37	0.48	-0.04	0.10	
D	Power					0.93	-0.03	-0.11	0.87	0.99	-0.10	0.96	-0.12	0.46	0.04	-0.01	-0.15	0.99	0.13	
E	Grid						-0.10	-0.12	0.76	0.94	-0.11	0.91	-0.24	0.39	-0.11	-0.12	-0.26	0.95	-0.03	
F	Climate ch.							0.13	0.26	-0.15	0.10	-0.05	0.65	0.54	0.49	0.40	0.66	-0.12	0.54	
G	Greenhouse								-0.18	-0.10	0.98	0.06	0.40	0.35	0.00	0.34	0.08	-0.09	-0.01	
H	Emissions									0.83	-0.18	0.79	0.04	0.44	0.10	0.16	-0.13	0.84	0.19	
I	Diesel										-0.08	0.97	-0.23	0.35	-0.08	-0.08	-0.23	1.00	0.00	
J	Oil / Petrol.											0.06	0.35	0.35	-0.02	0.29	0.04	-0.09	0.00	
K	Electricity												-0.18	0.40	-0.08	0.02	-0.10	0.97	-0.01	
L	Transport													0.73	0.84	0.58	0.53	-0.21	~~0.81~~	
M	Plane														0.66	0.30	0.37	0.37	~~0.75~~	
N	Airport															0.52	0.61	-0.07	~~0.96~~	
O	Flight																0.46	-0.05	0.41	
P	Cargo																	-0.21	0.57	
Q	Solar panel																		0.01	
R	Hydroelectricity																			
S	H-Q	0.84	0.06	-0.14	0.58	0.81	-0.02	-0.04	0.40	0.58	-0.05	0.56	-0.11	0.39	-0.05	-0.08	-0.16	0.59	0.02	
T	Tugliq	0.28	0.07	-0.23	-0.09	0.25	0.05	-0.09	-0.16	-0.08	-0.09	-0.10	-0;11	0.08	-0.14	-0.24	-0.16	-0.08	-0.10	0.72
U	Air Inuit	0.15	0.38	0.27	0.11	0.04	0.65	0.02	0.21	-0.01	-0.02	0.02	0.75	0.63	0.82	0.60	0.70	0.01	~~0.81~~	0.24
V	Canadian North / First Air	0.33	0.58	0.63	0.18	0.25	0.60	0.29	0.22	0.12	0.21	0.23	0.40	0.43	0.20	0.37	0.49	0.15	0.17	0.49

(1) Green is for coefficients between 0.90 and 1. yellow between 0.80 and 0.899 and orange between 0.70 and 0.799.
(2) Crossed-out boxes correspond to correlations invalidated by context: keywords appear in the same newspapers but not in the same articles.

A first group of words that converge on the theme of the energy production grid shows a network of correlations with coefficients close to 1. After manually checking the consistency of these results, the words “power”, “grid”, and “emissions” are excluded from the list in favour of the words “energy”, “diesel”, “electricity”, “solar/photovoltaic panel”, “Hydro-Québec”, and “Tugliq”, which are sufficient to encompass this theme. A second group of words converges on the theme of air transport, but the correlation network between the keywords is less clear than for the first. Nevertheless. Figure-A 4.a-2 shows that a reference to “Air inuit” or “Canadian North / First Air” is made for each issue that mentions air transport. It was therefore decided to exclude the words “airport”, “cargo”, “flight” and “plane / airplane” in favour of the more general term “transport” and the two actors “Air Inuit” and “Canadian North / First Air”. Finally, the words “sustainable” and “oil/petroleum” are more or less correlated with the word “greenhouse” but no conclusion is drawn from this: no interpretation seems really relevant. Having completed these refinement steps, the final list of keywords is presented in Tableau-A 4.a-3.

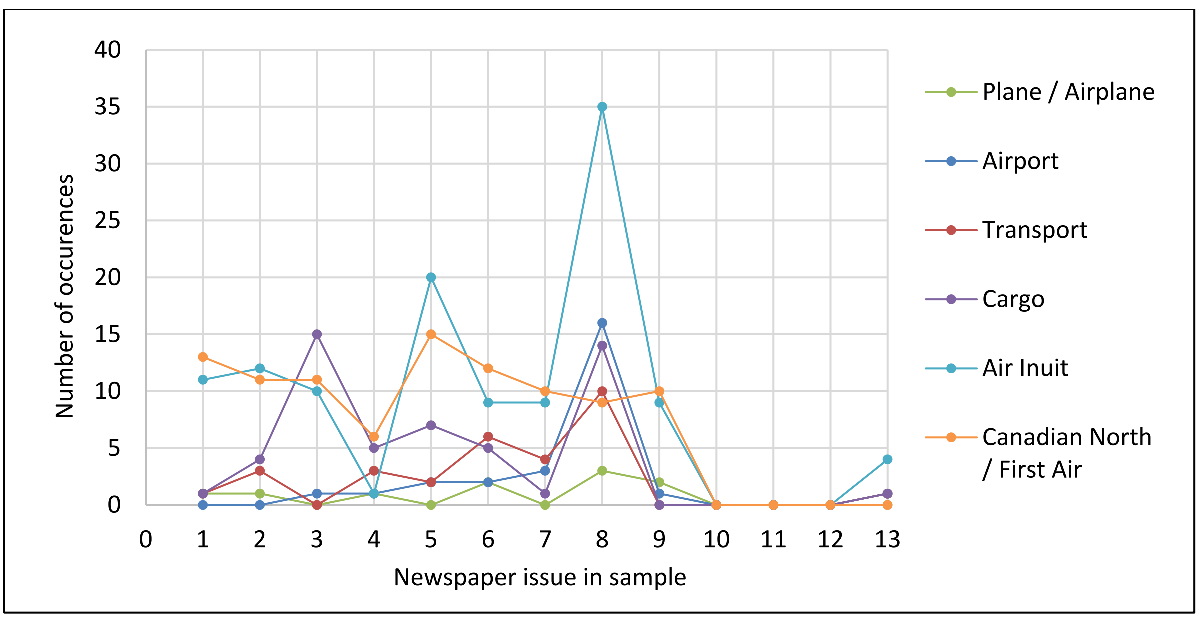


Figure-A 4.a-2 Representation of the second group of correlated words, on the theme of air transport

Tableau-A 4.a-3 Refined keyword list for searching articles and building the press corpus

Category	Keyword	French equivalent
1. General concepts	Energy	Énergie
	Sustainable	Durable
	Environment	Environnement
	Climate Change	Changement climatique
2. Energy sources and carriers	Diesel / Gasoline	Diesel / essence
	Oil / Petroleum	Pétrole
	Electricity	Électricité
3. Energy production	Solar / photovoltaic panel	Panneau solaire / photovoltaïque
	Hydroelectricity / Hydropower	Énergie hydraulique / Hydroélectricité
4. Energy uses	Greenhouse	Serre
	Transport	Transport
5. Energy system and environment actors	Hydro-Québec	Hydro-Québec
	Tugliq	Tugliq
	Tarquti	Tarquti
	Air Inuit	Air Inuit
	Canadian North / First Air	Canadian North / First Air

Finally, a number of adjustments were made to certain forms before lemmatisation in order to make the analysis more functional or relevant. In particular, some proper nouns or expressions composed of several words were modified so that they could be considered as a single form by IRaMuTeQ. These modifications are listed in Tableau-A 4.a-4. After lemmatisation, a mistake from IRaMuTeQ was detected. Some of the forms "serre" and "serres" have been lemmatised as conjugated verbs derived from the infinitive French verb "serrer". Among the active forms resulting from lemmatisation, the verb "serrer" therefore refers to greenhouse cultivation.

Tableau-A 4.a-4 Modifications made to nouns or expressions before lemmatisation

Initial name or expression	Modified version	Meaning or description
Canadian North	canadiannorth	A company
First Air	firstair	A company
Air Inuit	airinuit	A company
Hydro-Québec	hydroquébec	A company
Makivik or Société Makivik	sociétémakivik	An inuit stakeholder
Convention de la Baie James and du Nord Québécois	CBNJQ	A stakeholder agreement
Gaz à effet de serre	gazàeffetdeserre	Grenhouse gases

ANNEXE 4.b

ANALYSIS AND INTERPRETATION OF THEMATIC CLASSES

Tableau-A 4.b-1 Interpretation of class 1 and its subclasses

Subclasses	Description
Subclass 1.1 - Investments in energy and infrastructure	Investments in techno-economic sectors: mining, energy and transport sectors Case of transportation: airport infrastructure, airlines and electric vehicles Financial support for community and regional projects, and community well-being Case of greenhouse cultivation: community projects related to food insecurity Recurring participants in these investments: governments and Plan Nord
Subclass 1.2 - Infrastructure and sustainable socio-economic development	Infrastructure deficit: water treatment, energy security, internet access and housing Economy with the least environmental impact: viewpoint restricted to decarbonisation Quality of airport infrastructure and resilience to climate change Community participation in infrastructure governance
Subclass 1.3 - Levers for reconciliation: cooperation and infrastructure	Paths to environmentally sound development and reconciliation in Nunavik Cooperation between research, business and indigenous knowledge to develop Nunavik and manage the environment Research and corporate pressure on communities Infrastructure needs to be addressed Call to create a procurement policy for goods and materials to foster economic development
Subclass 1.4 - Dependence on petroleum products and transport	Economic and financial support for public services Supplying heating for buildings Support for local actors in the exploitation and use of oil Dependence on sea and air transport Deficit in maritime and road infrastructure Environmental impact of these energies and means of transport

Subclasses	Description
Subclass 1.5 - Mining, forestry and energy industries	Investment in these industries Economic contribution of these industries Link between the mining industry and the energy transition Environmental footprint of the mining sector Involvement of local and regional actors and landholding company
Subclass 1.6 - Fight against climate change	GHG emission reduction targets and measures Role played by governments Financial levers: funds, investments, taxes and pricing Electrification of transport and industry Indigenous participation in climate governance Inuit prejudice due to climate change
Subclass 1.7 - Food insecurity	Funds and investments in food security Poverty and food insecurity Impacts of climate change Historical and current effects of colonialism Inuit self-determination in food system development

Tableau-A 4.b-2 Interpretation of class 2 and its subclasses

Subclasses	Description
Subclass 2.1 - Building energy efficiency	Financial aid for energy efficiency Energy efficiency measures for housing Energy consumption and performance of buildings Construction standards for new housing Residential and commercial heating costs
Subclass 2.2 - Heat production and storage	Energy production and storage in greenhouses Geothermal potential Renewable heat production Fossil fuel consumption for heating
Subclass 2.3 - Decentralised solar power: photovoltaic and thermal	Financial support and deployment players Solar panel efficiency in the north Installed photovoltaic and thermal power Electricity storage solutions Quantity of energy generated Diesel consumption or GHG emissions avoided Current projects Residential installations and larger-scale parks

Tableau-A 4.b-3 Interpretation of class 3 and its subclasses

Subclasses	Description
Subclass 3.1 - Power generation and GHG emissions	GHG emissions from off-grid systems: absolute value and proportion in Québec Consumption of petroleum products for electricity generation Installed capacity of thermal power plants: absolute value and proportion Installed capacity of alternative generation: absolute value and proportion Current wind and solar projects Role of communities and stakeholders involved in electricity generation Growth in customer numbers and demand
Subclass 3.2 - Energy costs and revenues	Energy and electricity access prices and costs Production costs by mode of generation Heating costs Revenue sources from electricity production Hydrogen costs Prices of other goods and services: water, telephone, food, housing, household appliances, airline tickets
Subclass 3.3 - Mining sector: electricity and GHG emissions	Installed capacity of thermal power plants GHG emissions and diesel consumption Wind turbine installation at Raglan mine site Wind power capacity GHG emissions and diesel consumption avoided Quantity of electricity generated Charging stations for electric vehicles
Subclass 3.4 - Energy storage for electricity	Batteries: lithium-ion technology Green hydrogen Flywheels Combined wind power and storage Critical and strategic metals and minerals Electrical storage capacity and power Water reservoirs as a means of storing energy Need to reduce manufacturing costs Storage applications in transport Energy storage market

Tableau-A 4.b-4 Interpretation of class 4 and its subclasses

Subclasses	Description
Subclass 4.1 - Community projects to meet the challenges	Community activities and projects Greenhouse or hydroponic farming: projects, infrastructure and training Community programme to monitor traditional access trails Clean energy projects involving communities Community involvement in projects Integration of Inuit interests
Subclass 4.2 - Science, culture and traditional knowledge: societal levers for development	Integrating technology into the Inuit way of life Social network and information-sharing platform: siku Art and science as a catalyst for links between scientists and communities Contribution of scientific knowledge to sustainable development in Nunavik Sharing traditional and scientific knowledge Interdisciplinarity and interaction between players Diversity of research fields in Nunavik Access to studies and career paths
Subclass 4.3 - Adapting lifestyles to climate change	Effects of climate change on the Arctic Support for the development of clean technologies People displaced by climate change Adaptation of fishing and hunting practices Intergenerational discussions on the climate crisis Role of young people in the fight against the climate crisis Diversity of ideas and people to improve exchanges
Subclass 4.4 - Nunavik's food system: limitations and prospects	Community initiatives to combat food insecurity Access to traditional foods and purchased foods Cost of groceries in relation to income level Social and health consequences of food prices Air transport of foodstuffs to shops Greenhouse or container farming Remoteness as a cause of food insecurity Ability of food to meet nutritional needs Need for access to a source of energy to grow crops Necessary infrastructure, measures taken and stakeholders

Tableau-A 4.b-5 Interpretation of class 5 and its subclasses

Subclasses	Description
Subclass 5.1 - Inukjuak hydroelectric project development	Approval of power purchase agreement Electricity sales tariffs Approval of project environmental assessment Project stakeholders Plant capacity Number of inhabitants affected Conversion to electric heating Reduction in dependence on petroleum products
Subclass 5.2 - Alternative energy development: stakeholders, governance and community participation	Partnership between Hydro-Québec and Tarquti Energy Renewable energy projects: hydroelectric, solar, wind power Community consultation on projects and technologies Tarquti Energy: an Inuit-owned company responsible for project development Wind speed measurement Special cases: Inukjuak, Whapmagoostui, Kuujjuaarapik Fossil fuel combustion and dependenc
Subclass 5.3 - Managing water flows and reserves	Flow and water levels managed by Hydro-Québec Water discharges associated with hydroelectricity Small hydroelectric projects River water levels and impacts in Nunavik: the case of Kuujjuaq Groundwater and surface water pollution Dependence on river fishing for food: the case of Kuujjuaq

Tableau-A 4.b-6 Interpretation of class 6 and its subclasses

Subclasses	Description
Subclass 6.1 - Extractive activities: exploration, operation and site rehabilitation	The need to rehabilitate certain mining sites A system for classifying contaminated sites Financing the rehabilitation of mining sites Special case of abandoned mining exploration camps Rehabilitation stakeholders Protection of areas from exploration and exploitation Community concerns about environmental and health impacts

Subclasses	Description
Subclass 6.2 - Waste management	Financing waste management Storage and management of residual and hazardous materials Actors and their roles in waste management and social services Regulations on the distribution of plastic bags Prevention and awareness-raising
Subclass 6.3 - Assessment, consultation and protection mechanisms	Environmental and social impact assessment procedures Procedures used to assess projects Mechanisms stemming from the JBNQA Stakeholders in assessment procedures Public participation Climate change prevention and adaptation Biodiversity protection

Tableau-A 4.b-7 Interpretation of class 7 and its subclasses

Subclasses	Description
Subclass 7.1 - General impacts of climate change	Impacts of climate change on biodiversity Rising temperatures Change in rainfall patterns Melting of sea ice and permafrost Displacement or change of ecosystems Invasive species and bacterial growth Consequences exacerbated in the far north Impacts on northern culture and the health of inhabitants Aviation disrupted by the weather
Subclass 7.2 - Health impacts related to viruses and mosquitoes	Animal reservoirs of viruses Transmission by mosquitoes Californian serogroup viruses Study of the ecology of these viruses Prospects for detection and mitigation of transmission
Subclass 7.3 - Changing behaviour of beavers and other species	Impacts on Arctic char migration Monitoring of beaver activity Water quality in dyked watercourses Hunting and trapping associations Concerns about seals Monitoring of other wildlife species

Subclasses	Description
Subclass 7.4 - Disruption of caribou migration	Changes in migration dates Variable environmental indicators: temperature, precipitation, snow cover, ice formation and thawing, emergence of food resources, etc. Calving conditions for females Potential impact on survival and reproduction
Subclass 7.5 - Resilience and housing quality in a northern climate	Taking account of culture and needs Overcrowding in dwellings Poor ventilation in dwellings Building technologies adapted to Arctic regions Permafrost thawing and erosion

Tableau-A 4.b-8 Interpretation of class 8 and its subclasses

Subclasses	Description
Subclass 8.1 - Adapting and upgrading the aircraft fleet	Adaptation of a cargo aircraft with a loading door unique in the world Fuel savings and operating costs Transport of bulky items: land vehicles or mining equipment Short gravel airstrips: a disincentive to the purchase of larger aircraft Air Inuit's fleet of aircraft
Subclass 8.2 - Dependence on airfreight supply	Airline operations during the COVID-19 pandemic Essential service for Nunavik: food, medicine, goods and workers Quantity or mass of freight transported each year Essential element of the Nunavik economy
Subclass 8.3 - Airline Governance	Chair of the Board of Directors of the airlines Executive members of Makivik Corporation Makivik Corporation's shipping joint venture Financing of Inuit businesses Merger of First Air and Canadian North Lobbying activities
Subclass 8.4 - Aviation's social role for young people	The pilot's profession as a role model Promoting the pilot's profession for women Training opportunities for the pilot's profession A means of contributing to socio-economic development A passion for aviation and pride in flying Partnerships with the Aviation and Space Museum Partnerships with industry Opportunities to discover the sector

ANNEXE 4.c

VARIABLE ANALYSIS: CORPUS OVERVIEW AND THEMATIC FRAMEWORK ANALYSIS

A profile of the corpus is drawn up using the variables introduced in section 4.4.2.5. First, Figure-A 4.c-1 illustrates the distribution of scales and newspapers in the corpus. Of the 2,836 sections of text, the majority come from local newspapers, despite the greater number of provincial newspapers used in the construction of the corpus. This shows that the latter provide relatively little media coverage of Nunavik. Moreover, the national scale is in the minority, which is not surprising since only one newspaper was included in the press review.

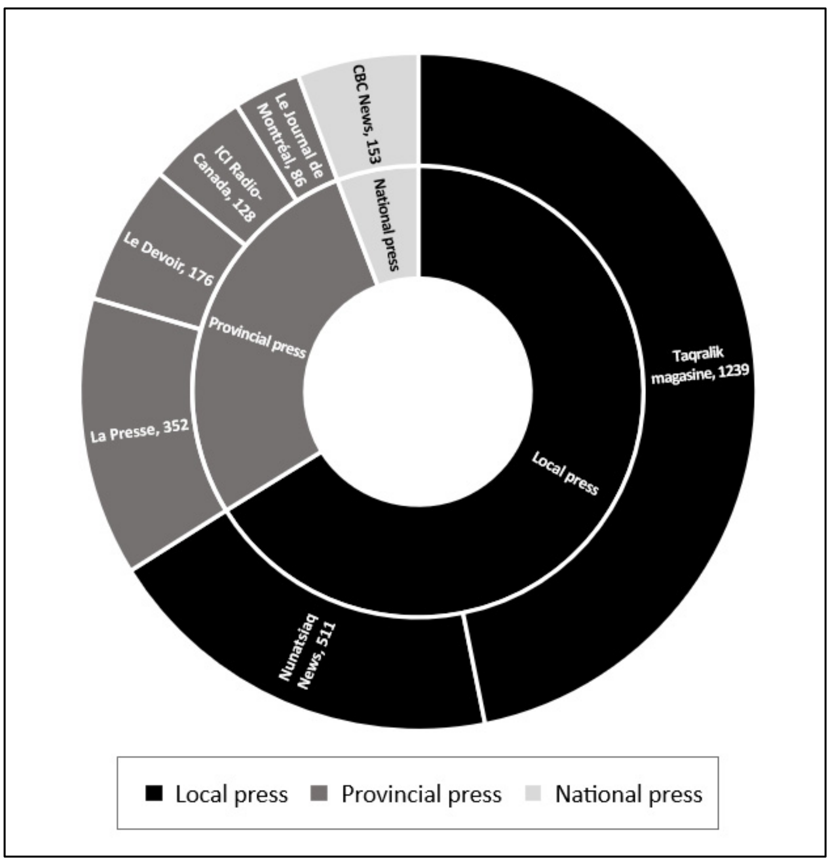


Figure-A 4.c-1 Occurrence of scales and newspapers in the corpus

In addition, the distribution of the themes defined in 4.4.2.5 and identified qualitatively during the construction of the corpus is unbalanced (Figure-A 4.a-2). The theme of energy predominates, followed by the themes of the environment, aviation and climate. In contrast to aviation, the more general theme of transport hardly appears at all. Conversely, the specific theme associated with natural areas is logically less represented than the more general theme of the environment.

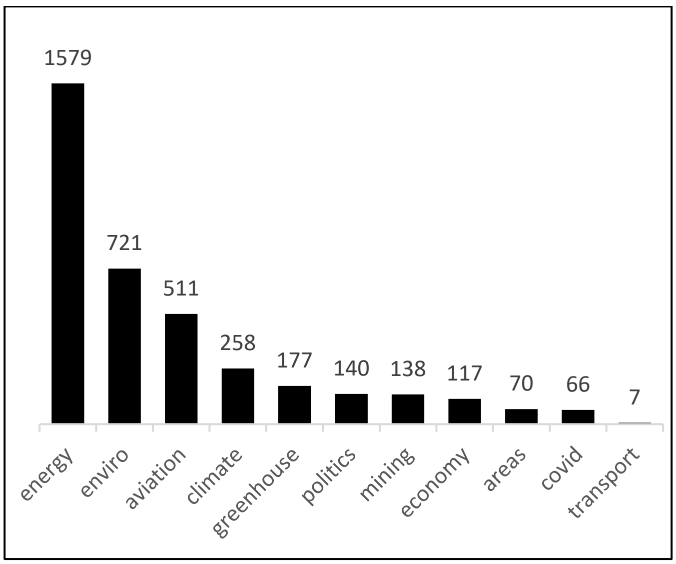


Figure-A 4.c-2 Occurrence of themes in the corpus

Finally, the distribution of years in the corpus seems to indicate that the subject covered by the press review has been receiving increasing media coverage since 2017 (Figure-A 4.c-3), although the articles selected for that year only cover the second half of the year. It would be interesting to extend the corpus over the years following 2022 to validate or invalidate the trend.

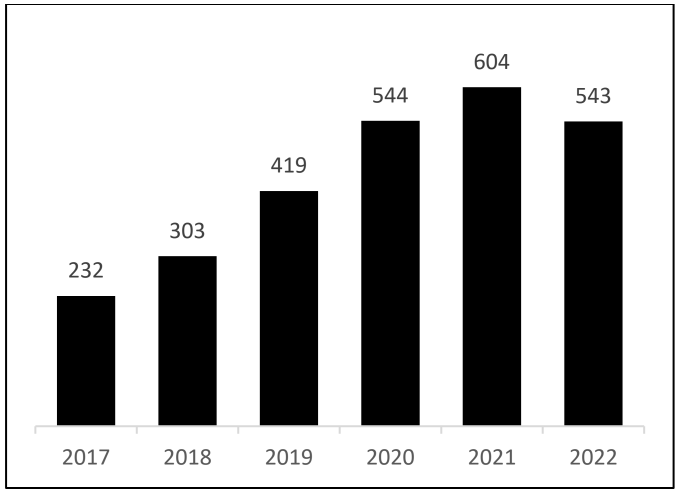


Figure-A 4.c-3 Occurrence of years in the corpus

Logically, local newspapers are in the majority, but their distribution varies, and they are significantly less numerous or even in the minority in some classes. Firstly, Taqralik is disproportionately dominant in classes 6 and 8, while the newspaper is relatively absent from classes 5 and 3. In the former, Nunatsiaq News is disproportionately dominant, while provincial newspapers dominate the latter. Class 1 is notable for the emergence of CBC News and ICI Radio-Canada. However, it is difficult to interpret this distribution further, particularly for the low-value variables where the contrasts are overwhelmed by the high values. Figure-A 4.c-4, Figure-A 4.c-5, Figure-A 4.c0-6, and Figure-A 4.c-7 provide more information: they show the statistical links between classes and newspapers, scales, years and themes.

Firstly, a few spatial trends emerge. It appears that classes 2 and 4 show relatively few contrasts in terms of newspapers and scales, i.e. the subjects associated with them are treated in a balanced way. In terms of scales, class 5 is also balanced, but this is due to a compensatory contrast between the two local newspapers (see Figure-A 4.c-4 and Figure-A 4.c-5). Class 5 is largely associated with Nunatsiaq News, and conversely with Taqralik Magasine. Thus, the development of alternative energies and the Inukjuak hydroelectric project is an important element in the discourse of the Nunatsiaq News newspaper, and significantly less so in the Taqralik newspaper. Finally, class 1 shows a statistical association with CBC News, and to a lesser extent with the provincial scale represented by ICI Radio-Canada. Class 3 is also distinguished by the prevalence of La Presse and Le Devoir and by a relatively strong statistical link with them, resulting in a marked link with the provincial scale.

Secondly, some temporal trends can be observed. While class 2 is mainly associated with the year 2017, class 3 is associated with the year 2022. Thus, it seems that the discourse surrounding decentralised energy peaked in 2017, while the transformation of decentralised systems was at the heart of the discourse in 2022. These two peaks are respectively linked to media coverage of small-scale photovoltaic projects and wind power projects. Class 8 is associated with the year 2020, and to a lesser extent with the year 2021, partly because of the covid-19 pandemic which affected air traffic over this period, as suggested by the prevalence of the *theme_covid variable in Figure-A 4.c-7. Debates over airline financing, as well as socio-economic considerations, highlighting the region's dependence on the airline sector, also contributed to this statistical peak. For class 5, the 2019 peak corresponds to the period when the Inukjuak hydroelectric project came to fruition. Finally, classes 1 and 4, and to a lesser extent classes 6 and 7, are relatively balanced. However, there were more speeches about the operation of the Kativik Environmental Quality Commission in class 6 in 2017 and 2018. In addition, speeches about the impacts of climate change on biodiversity were also common in 2019 and 2021 in class 7.

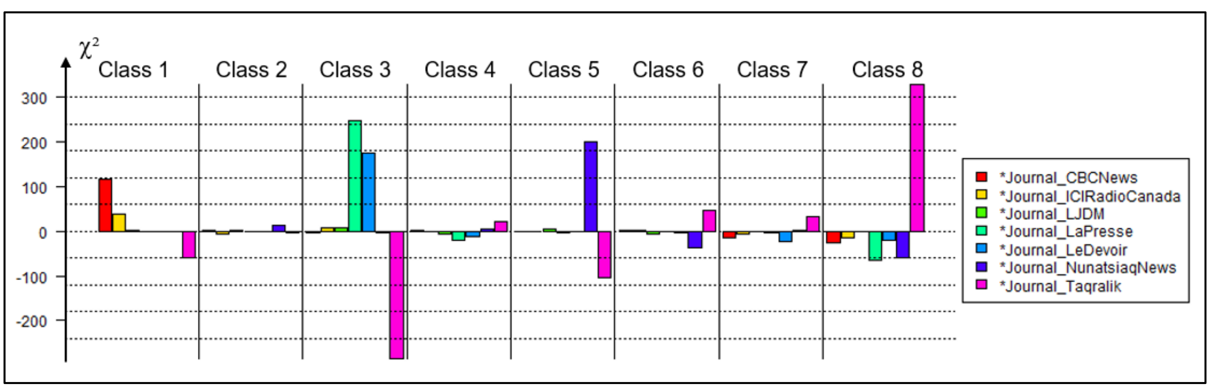


Figure-A 4.c-4 Links between class and newspaper coverage

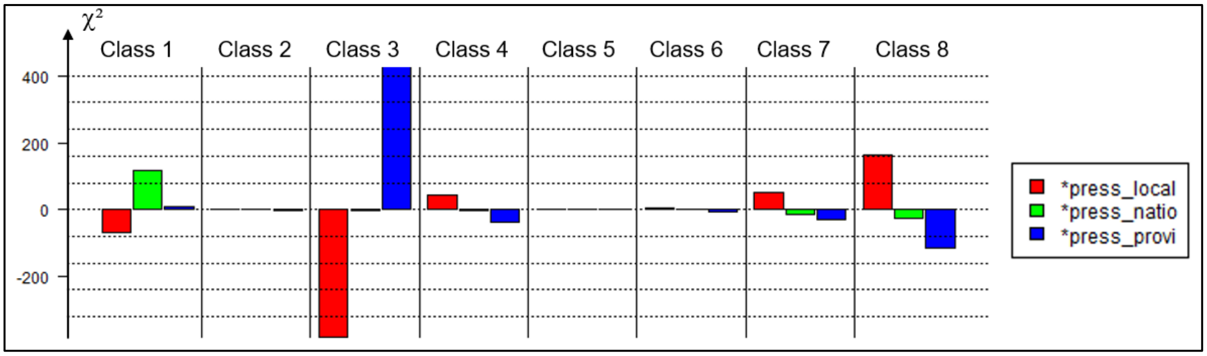


Figure-A 4.c-5 Links between class and scale coverage

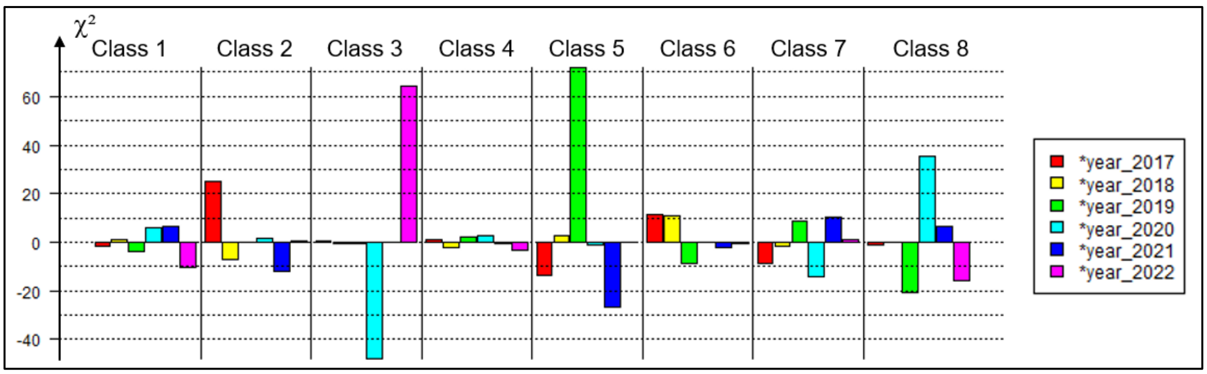


Figure-A 4.c0-6 Links between classes and years of the period studied

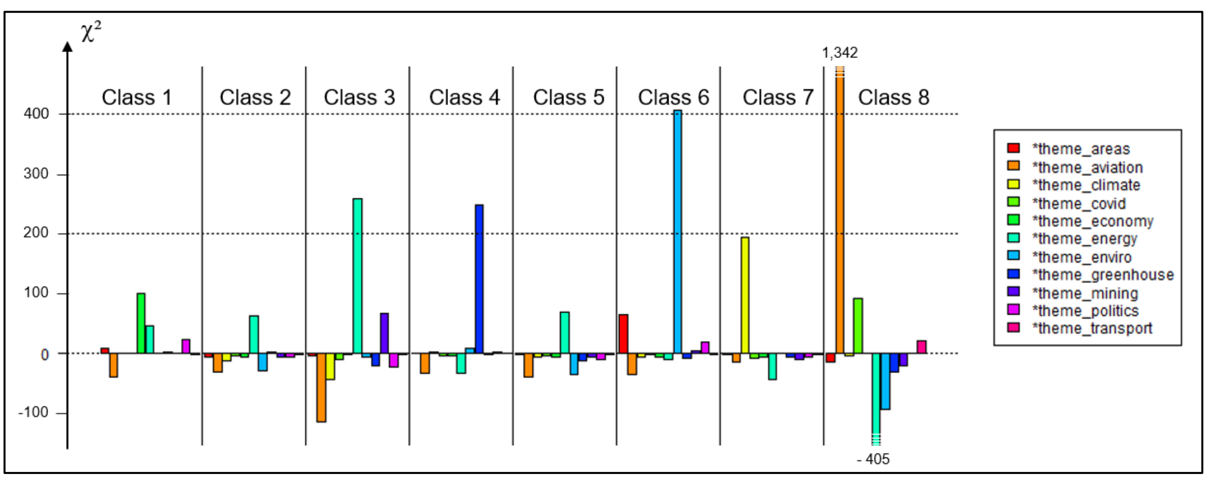


Figure-A 4.c-7 Links between class and themes identified during the press review

ANNEXE 4.d

REFERENCES FOR INDICATOR SELECTION

Tableau-A 4.d-1 References suggested by Chaubier and al. (submitted, not published)

Set n°	Series name	References
1	Sustainable Energy Development Index	Iddrisu and Bhattacharyya (2015)
2	Regulatory Indicators for Sustainable Energy	Banerjee and al. (2017), ESMAP and The World Bank (2018), World Bank Group (2014)
3	Energy sustainability index	Doukas and al. (2012)
4	Energy sustainability index	Mainali and al. (2014)
5	Energy indicators for sustainable development	IAEA and al. (2005), Vera and al. (2005), Vera and Abdalla (2006), Vera and Langlois (2007)
6	Sustainable energy development indicators for EU energy policy 1	Streimikiene and Šivickas (2008)
7	Sustainable energy development indicators for EU energy policy 2	Štreimikienė (2015)
8	Sustainable energy development indicators for EU energy policy 3	Siksnelyte and al. (2019)
9	Aggregated energy security performance indicator	Martchamadol and Kumar (2013)
10	The U.S. Energy Security Risk (Index)	Global Energy Institute and U.S. Chamber of commerce (2018)
11	Risky External Energy Supply index	Le Coq and Paltseva (2009)
12	Electricity generation security of supply indicators	Portugal-Pereira and Esteban (2014)
13	Energy security index 1	Sovacool and al. (2011)
14	Energy security index 2	Sovacool (2013)
15	Renewable Energy Sustainability Index	Cîrstea and al. (2018)
16	Renewable Energy Responsible Investment Index	Lee and Zhong (2015)
17	Multidimensional Energy Poverty Index	Nussbaumer and al. (2012)
18	Indicators for sustainable energy development for Iceland	Gunnarsdottir and al. (2022)

Tableau-A 4.d-2 Other references used to build the final set of indicators

N°	Document name	References
A	Energy, transport and environment indicators	Eurostat (2017, 2020)
B	Data and energy efficiency indicators definitions | Odyssee Database	ODYSSEE-MURE (2020)
C	Local Governance in Just Energy Transition: Towards a Community-Centric Framework	Swarnakar and Singh (2022)
D	Qualitative Stakeholder Analysis for a Swedish Regional Biogas Development: A Thematic Network Approach	Rambaree and al. (2021)
E	Developing a framework for sustainable development indicators for the mining and minerals industry	Azapagic (2004)
F	Classification of indicators measuring environmental sustainability of mining and processing of copper	Fuentes and al. (2021)
G	Eco-efficiency indicator framework implemented in the metallurgical industry: part 2—a case study from the copper industry	Rönnlund and al. (2016)
H	Calculation of levelized costs of electricity for various electrical energy storage systems	Obi and al. (2017)

APPENDICE A

PERCEPTION ET IMPLICATION DANS LES PROJETS DE TRANSITION : BILAN ET ENJEUX POUR LES COMMUNAUTÉS

Au Nunavik, les projets, et particulièrement ceux de l'industrie ou du secteur de l'énergie, sont soumis à une évaluation qui diffère du reste du Québec. Elle est encadrée par le chapitre 23 de la convention de la Baie-James et du nord québécois (CBJNQ) et le chapitre II de la loi sur la qualité de l'environnement et gérée par la Commission de la qualité de l'environnement Kativik (CQEK) (s. d.-b). Elle prévoit notamment une étude d'impact sur le milieu social et environnemental ainsi qu'un processus d'information et de consultations publiques. Ce dernier offre la possibilité aux personnes et milieux concernés directement ou indirectement par un projet d'en prendre connaissance et de partager leur point de vue (CQEK, s. d.-a).

Cependant, si la prise en compte de l'acceptabilité sociale dans les projets de transition permet de donner la parole aux communautés autochtones, la distribution des pouvoirs décisionnels relatifs à l'approvisionnement énergétique au Nunavik restreint tout de même leur engagement à un seuil qui n'est pas optimal. D'ailleurs, tout projet énergétique, inuit ou non inuit, est soumis à la décision d'Hydro-Québec et de la Régie de l'énergie (Harbour-Marsan, 2018). D'autre part, les éléments du discours nécessaires à la participation sont ceux des entreprises et organismes et ils s'imposent aux membres des communautés désireux de participer. Ainsi, cette contrainte a pour conséquences d'exclure des personnes et leurs points de vue des échanges : les femmes, les jeunes et les individus aux mœurs plus traditionnelles (Fortin, 2022). En particulier, le monopole de la société d'état Hydro-Québec sur la distribution de l'énergie serait une cause majeure d'échec du déploiement de technologies d'énergies renouvelables. De plus, une posture colonialiste de la société d'état vis-à-vis des projets communautaires, se traduisant par un manque de confiance envers la capacité des communautés à implémenter leurs projets, a pu aussi être un frein à leur développement, à l'image de la centrale au fil de l'eau d'Inukjuak (Rodon et al., 2021).

Ce cas d'ascendance d'Hydro-Québec sur les acteurs locaux fait écho au cas des projets miniers. L'analyse de Fortin (2022) montre que les communautés autochtones subissent une altération de leur habilité à négocier et à délibérer selon des « dimensions silencieuses » de l'acceptabilité sociale dont font partie « les relations de pouvoir entre les acteurs ». La deuxième « dimension silencieuse » intègre « les perceptions du projet » qui peuvent varier selon l'individu et la catégorie d'acteur. En particulier, les inuits du Nunavik comprennent la nécessité d'une transition sur leur territoire mais n'y ont pas les mêmes intérêts que les acteurs non-inuits. Les leurs sont fondamentalement associées aux caractéristiques socio-environnementales de leur communauté ainsi qu'aux spécificités des technologies renouvelables qui leur sont proposées. Aussi, la capacité des promoteurs de projets énergétiques à s'adapter aux modes de gouvernance et de vie inuit est une clé vers le bon déroulé d'une participation communautaire et l'acceptation d'un projet (Paquet, 2022).

De plus, la « dimension silencieuse » que constituent les « émotions » engendrées par le projet sont souvent mises de côté. Cela constitue une limite au processus de dialogue entre les acteurs et un frein à l'acceptation sociale. En effet, le souvenir de préjudices - en particulier dans le cas du passé colonial des communautés autochtones - peut nuire au dialogue. En outre, les projets impliquant une dégradation de l'environnement peuvent susciter des émotions. Enfin, les « impacts [d'un projet] sur la cohésion sociale » peuvent se manifester par une polarisation des positions qui affaiblirait la cohésion sociale (J. Fortin, 2022). Ces dimensions de la participation communautaire aux projets de transition peuvent être identifiées dans une variété de démarches d'acceptation sociale, dont certaines ont moins de chances de succès que d'autres. Cela dépend notamment de la définition que les acteurs de la démarche ont de l'acceptabilité sociale, ainsi que des postulats sur lesquels ils s'appuient (Batellier, 2016). Par ailleurs, l'intitulé « acceptabilité sociale » ne fait pas l'unanimité dans la littérature scientifique et cherche encore une définition et un cadre plus universel. En effet, il est surtout utilisé par des acteurs publics ou privés : une audience chez qui il rencontre du succès malgré un « caractère relatif et flou » (Boissonade et al., 2016).

Cet échec à faire participer pleinement les populations à l'implémentation de projets de transition est à double tranchant. D'une part, cela peut affecter la capacité des parties prenantes à résoudre les conflits entourant les projets en étouffant les opportunités de débats constructifs (Friser & Yates, 2021). D'autre part, ces débats peuvent être à l'origine de rencontres entre des visions du monde différentes, ce qui peut participer à des progrès sociétaux à une plus large échelle (Noury & Seguin, 2021). Effectivement, le succès des projets énergétiques et de la participation autochtone n'est pas qu'un enjeu environnemental. Il pourrait être un tremplin vers l'équité et la réconciliation des populations au Nunavik (Hoicka et al., 2021; Paquet et al., 2021). D'autre part, bien que la protection de l'environnement compte parmi les motivations autochtones à participer à la transition énergétique, les Inuits ont aussi un intérêt croissant pour la question en raison des bénéfices socio-économiques et politiques d'une telle transition. En particulier, c'est l'enjeu de leur autonomie qui rentre en compte. Cependant, les inquiétudes et intérêts sont marqués par une différence significative entre l'échelle des communautés et des individus et celle de la société inuite. En effet, les habitants du Nunavik restent particulièrement soucieux de ses conséquences sur l'environnement, les animaux sauvages et leur communauté (Harbour-Marsan & Lasserre, 2021).

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