Regular Session

RS

Milwaukie City Council

CITY OF MILWAUKIE

2368th Meeting

COUNCIL REGULAR SESSION

REVISED AGENDA

City Hall Council Chambers, 10722 SE Main Street
& Zoom Video Conference (www.milwaukieoregon.gov)

NOVEMBER 1, 2022

(Revised October 28, 2022)

Council will hold this meeting in-person and through video conference. The public may attend the meeting by coming to City Hall or joining the Zoom webinar, or watch the meeting on the city's YouTube channel or Comcast Cable channel 30 in city limits. **For Zoom login** visit https://www.milwaukieoregon.gov/citycouncil/city-council-regular-session-335.

To participate in this meeting by phone dial **1-253-215-8782** and enter Webinar ID **831 8669 0512** and Passcode: **023745**. To raise hand by phone dial *9.

Written comments may be delivered to City Hall or emailed to ocr@milwaukieoregon.gov. Council will take verbal comments.

Note: agenda item times are estimates and are subject to change. **Page #**

1. **CALL TO ORDER** (6:00 p.m.)
   - A. **Pledge of Allegiance**
   - B. **Native Lands Acknowledgment**

2. **ANNOUNCEMENTS** (6:01 p.m.) **2**

3. **PROCLAMATIONS AND AWARDS**
   - A. **Veterans Day – Proclamation** (6:05 p.m.) **4**
     Presenters: Mark Gamba, Mayor, and
     Scott Stauffer, City Recorder

4. **SPECIAL REPORTS**
   - ~~A. **City Manager Updates – Report**~~ (removed from the agenda)
     ~~Staff: Ann Ober, City Manager~~

5. **COMMUNITY COMMENTS** (6:10 p.m.)
   To speak to Council, please submit a comment card to staff. Comments must be limited to city business topics that are not on the agenda. A topic may not be discussed if the topic record has been closed. All remarks should be directed to the whole Council. The presiding officer may refuse to recognize speakers, limit the time permitted for comments, and ask groups to select a spokesperson. **Comments may also be submitted in writing before the meeting, by mail, e-mail (to ocr@milwaukieoregon.gov), or in person to city staff.**

6. **CONSENT AGENDA** (6:15 p.m.)
   Consent items are not discussed during the meeting; they are approved in one motion and any Council member may remove an item for separate consideration.
   - A. **Approval of Council Meeting Minutes of:** **6**
     1. **October 4, 2022, work session, and**
     2. **October 4, 2022, regular session.**

6. **CONSENT AGENDA (continued)**

~~**B. Appointments to the Transportation System Plan Advisory Committee (TSPAC) – Resolution**~~ (removed from the agenda)

C. An Appointment to the Ledding Library Board – Resolution **13**

7. **BUSINESS ITEMS**

A. Annexation of 5731 SE Laurel Street – Ordinance (6:20 p.m.) **17**
Staff: Brett Kelver, Senior Planner

B. New Building Energy and Climate – Resolutions, continued (6:30 p.m.) **41**
Staff: Natalie Rogers, Climate & Natural Resources Manager

8. **PUBLIC HEARINGS**

A. None Scheduled.

9. **COUNCIL REPORTS** (8:40 p.m.)

10. **ADJOURNMENT** (8:45 p.m.)

Meeting Accessibility Services and Americans with Disabilities Act (ADA) Notice
The city is committed to providing equal access to public meetings. To request listening and mobility assistance services contact the Office of the City Recorder at least 48 hours before the meeting by email at ocr@milwaukieoregon.gov or phone at 503-786-7502. To request Spanish language translation services email espanol@milwaukieoregon.gov at least 48 hours before the meeting. Staff will do their best to respond in a timely manner and to accommodate requests. Most Council meetings are broadcast live on the city's YouTube channel and Comcast Channel 30 in city limits.

Servicios de Accesibilidad para Reuniones y Aviso de la Ley de Estadounidenses con Discapacidades (ADA)
La ciudad se compromete a proporcionar igualdad de acceso para reuniones públicas. Para solicitar servicios de asistencia auditiva y de movilidad, favor de comunicarse a la Oficina del Registro de la Ciudad con un mínimo de 48 horas antes de la reunión por correo electrónico a ocr@milwaukieoregon.gov o llame al 503-786-7502. Para solicitar servicios de traducción al español, envíe un correo electrónico a espanol@milwaukieoregon.gov al menos 48 horas antes de la reunión. El personal hará todo lo posible para responder de manera oportuna y atender las solicitudes. La mayoría de las reuniones del Consejo de la Ciudad se transmiten en vivo en el canal de YouTube de la ciudad y el Canal 30 de Comcast dentro de los límites de la ciudad.

Executive Sessions
The City Council may meet in executive session pursuant to Oregon Revised Statute (ORS) 192.660(2); all discussions are confidential; news media representatives may attend but may not disclose any information discussed. Final decisions and actions may not be taken in executive sessions.

RS Agenda Item 2

Announcements

Mayor's Announcements – November 1, 2022

- **Leaf Drop – Saturdays in Nov. (5 & 19) and Dec. (3, 10, & 17) - 7 AM to 2 PM**
  - Free leaf disposal events for Milwaukie residents
  - Bring along utility bill (e-bill or paper bill) as proof or residency
  - Service is free, but city will collect non-perishable food for local families in need.
  - Johnson Creek Building, 6101 SE Johnson Creek Blvd.

- **Online Watersheds Workshop 3-Part Series – Nov. 8, 9, & 10 (12 AM to 1 PM)**
  - Nov. 8 – Get to Know North Clackamas Watersheds
  - Nov. 9 – Wildlife in North Clackamas Watersheds
  - Nov. 10 – North Clackamas Watersheds, People, and Place
  - Learn more and RSVP at tinyurl.com/ncwatersheds

- **Parks Community Forum – Thu., Nov. 10 (6-7:30 PM)**
  - Attend a special presentation about the current state of Milwaukie's parks and the future plan for some of the community's most treasured spaces.
  - Forum will include a question-and-answer session.
  - Forum held at Ledding Library (10660 SE 21st Ave.)
  - Learn more about parks at www.ourmilwaukieparks.com

- **Thanksgiving Farmers Market – Sun., Nov. 20 (9:30 AM – 2 PM)**
  - Learn more at milwaukiefarmersmarket.com

- **City Manager Open Door Session – Tue., Nov 29 (9-10 AM)**
  - Ask questions, raise concerns, or just find out more about what the city is doing.
  - No sign-up necessary. First-come, first-served, at City Hall, 10722 SE Main St.

- **Election Day is November 8!**

- **LEARN MORE AT WWW.MILWAUKIEOREGON.GOV OR CALL 503-786-7555**

RS Agenda Item 3

Proclamations & Awards

CITY OF MILWAUKIE

PROCLAMATION

WHEREAS the United States first proclaimed November 11, 1919, as Armistice Day to mark the end of World War I, the "War to End All Wars," and to solemnly reflect on the horrific consequences of all wars, and

WHEREAS since 1919, the 11th day of the 11th month has come to be a time to recognize the contributions made by the millions of men and women who answered Our Nation's call to arms in the pursuit of world peace, and

WHEREAS Veterans Day brings communities together to honor military veterans and their legacy of selfless services and sacrifice and to remember the millions of civilians and military personnel who have died or been injured by war, and

WHEREAS the United States Department of Defense recognizes that the risk of future wars will be greatly increased by climate chaos and the resulting forced migrations due to devastating starvation, inundation, fires, flooding and drought and we should do everything necessary to decrease those effects, and

WHEREAS the City of Milwaukie has been proud to partner with American Legion Post 180 and the Susannah Lee Barlow Chapter of the Daughters of the American Revolution to recognize and honor veterans in community who did not come home, and

WHEREAS the City of Milwaukie recognizes the sacrifices made by the those who served our country so that all may pursue life, liberty, and happiness.

NOW, THEREFORE, I, Mark Gamba, Mayor of the City of Milwaukie, a municipal corporation in the County of Clackamas, in the State of Oregon, do hereby proclaim **November 11, 2022,** to be **Veterans Day** in the City of Milwaukie.

IN WITNESS WHEREOF, and with the consent of the City Council of the City of Milwaukie, I have hereunto set my hand on this 1st day of November 2022.

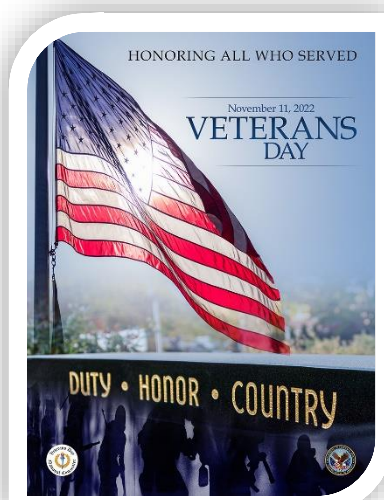
____

Mark F. Gamba, Mayor

ATTEST:

____

Scott S. Stauffer, City Recorder



RS Agenda Item 5

Community Comments

18:18:53 From City Recorder to Hosts and panelists:

Chat is now open - please only comment if you wish to speak to Council.

18:19:00 From City Recorder to Hosts and panelists:

Council is taking comments on non-agenda items at this time.

18:51:13 From City Recorder to Hosts and panelists:

Council will take public comment on this item, after the staff report. If you would like to ask a question please raise your hand so we know to call on you when the mayor calls for comment.

19:32:11 From City Recorder to Hosts and panelists:

As Council is done taking comment we will close the Zoom chat.

RS Agenda Item 6

Consent Agenda

CITY OF MILWAUKIE

COUNCIL WORK SESSION

City Hall Council Chambers, 10722 SE Main Street
& Zoom Video Conference (www.milwaukieoregon.gov)

MINUTES

OCTOBER 4, 2022

Council Present: Councilors Adam Khosroabadi, Lisa Batey, Desi Nicodemus, Council President Kathy Hyzy, and Mayor Mark Gamba

Staff Present:
Justin Gericke, City Attorney
Nicole Madigan, Deputy City Recorder
Adam Moore, Parks Development Coordinator
Ann Ober, City Manage
Peter Passarelli, Public Works Director
Natalie Rogers, Climate & Natural Resources Manager
Scott Stauffer, City Recorder

Mayor Gamba called the meeting to order at 4:03 p.m. and noted that Councilors Batey and Nicodemus were running late and would arrive at the meeting later.

1. Tree Board – Annual Update

Passarelli noted there were no members of the Tree Board in attendance and named the members of the board and commended their work on reviewing the tree code.

Passarelli noted a vacancy on the Tree Board and that applications were being accepted. **Passarelli** provided an overview of the board's accomplishments.

Passarelli presented the qualifications that led the city to be awarded the Tree City USA award for 2021. **Passarelli** mentioned that about 1,362 trees had been planted by the city, the North Clackamas and Johnson Creek watershed councils, and private developments.

Passarelli presented on some of the aspects that qualified the city for the Tree USA Growth award. **Passarelli** stated that more public trees were planted than removed and that with a new electronic permitting system the city could be able to better track the planting to removal ratio for private trees.

Passarelli reviewed ongoing projects that staff and the Tree Board had been working on which included continued outreach for the private tree code, the Arbor Day event on October 22, application submissions for Tree City awards due in December, the leaf drop events at public works in November and December, and updates to the website.

Passarelli presented details for the Arbor Day event. **Mayor Gamba** asked where the Friends of Trees event would start and **Passarelli** advised it would start across from City Hall at 9 a.m. **Passarelli** and **Rogers** shared additional Arbor Day activities. **Passarelli** noted this was the fourth event the city had worked with Friends of Trees. **Mayor Gamba** and **Passarelli** discussed where the Friends of Trees would be planting on Arbor Day.

Passarelli shared upcoming projects and events for 2022 and 2023 that included a focus on community engagement for the new tree code and making updates to the new permitting system. **Passarelli** mentioned that staff and the Tree Board would be reviewing the commercial tree code for the Climate Equitable Communities project. **Council President Hyzy** and **Rogers** discussed when the commercial tree code requirements would apply and what type of requirements were included.

Passarelli noted work with the engineering department to update the Public Works (PW) Standards for trees in urban forests and that the Tree Board would like to circle back to a heritage tree program. **Mayor Gamba** and **Council President Hyzy** commented on whether a heritage tree program is necessary with the tree code in place. **Passarelli** stated the board would formulate a plan for the program and staff would evaluate the ease of implementation.

Passarelli mentioned an upcoming Friends of Trees event in April and Arbor Day 2023. **Council President Hyzy** and **Rogers** discussed giveaway trees at the upcoming 2022 Arbor Day event. **Mayor Gamba**, **Passarelli**, and **Rogers** discussed the Friends of Trees event in April of 2023.

Mayor Gamba, Passarelli, and **Council President Hyzy** commented on the commercial tree code.

The group discussed partnerships for watershed preservation and restorations plantings for private properties.

2. Park and Recreation Board (PARB) – Annual Review

Rogers shared the names of the current PARB members, acknowledged those who had resigned, and mentioned that PARB was accepting applications for youth members. **Rogers** presented PARB's accomplishments for 2022 which included 2,500 pounds of ivy removed during the Earth Day event.

Rogers acknowledged PARB's engagement role with the parks development projects and presented PARB's goals that focused on equitable engagement, updating the board's bylaws, developing a tracking system for goals, partnering with Tree Board on orchards in public parks, and advocating for a universal ability playground.

Rogers detailed how PARB had been engaging with the community during the park projects development process and shared plans for PARB in 2023. **Rogers** encouraged community members to attend PARB meetings and advised how those with a parks facility concern can submit a facility request through the North Clackamas Parks and Recreation District (NCRPD) website.

3. Parks Operations and Maintenance – Discussion

Passarelli noted that the discussion would focus on the city's operations and maintenance of parks only and not on providing recreation and adult services, though the city was working with a consultant to analyze offering those services. **Passarelli** mentioned considerations for partnering with NCPRD to handle the recreation and adult services and the management of North Clackamas Park.

Passarelli presented a six-year budget forecast that started July 2023. **Mayor Gamba** asked what the delegated intergovernmental agreement (IGA) was for and **Passarelli** responded it would be revenue from the Oregon State Marine Board for the dock removal and for other possible small grants. **Passarelli** noted that operating expenses were based on assumptions of what the city would need and that per the analysis it appeared that there were sufficient resources to cover expenses for the first five years but a decline in the operating income was noticeable starting in the sixth year. **Council President Hyzy** and **Passarelli** discussed the general fund allocations and **Passarelli** detailed what staff positions will be included in the parks division.

It was noted that Councilor Batey arrived at the meeting at 4:56 p.m.

The group discussed park fund allocations.

Passarelli presented cost details associated with material services and contractual support. The group discussed how repair and maintenance costs were calculated.

Passarelli presented plans for utilizing existing equipment and for purchasing a lawn mower. **Councilor Batey** and **Ober** discussed if equipment would be acquired from NCPRD. The group discussed how maintenance needs would be met by city facility technicians and contract specialists.

Passarelli mentioned that the city had a contract in place with the consultant firm FCS Group to develop methodology for an interim parks system development charge (SDC) that can be used to manage parks. **Councilor Batey** and **Passarelli** discussed the city's need for developing its own method for SDCs.

It was noted that Councilor Nicodemus arrived at the meeting at 5:12 p.m.

Passarelli stated that the city is working with Ballard King and Associates, which has experience working with the City of Happy Valley and NCPRD, to analyze how the city could offer recreation services.

Ober informed Council there would be continued follow up regarding parks, that the SDC methodology would be before Council in December, and the recreations services analysis would follow in a few months.

4. Adjourn

Mayor Gamba adjourned the meeting at 5:14 p.m.

Respectfully submitted,

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Nicole Madigan, Deputy City Recorder

CITY OF MILWAUKIE

2366th Meeting

COUNCIL REGULAR SESSION

MINUTES

OCTOBER 4, 2022

City Hall Council Chambers, 10722 SE Main Street
& Zoom Video Conference (www.milwaukieoregon.gov)

Council Present: Councilors Adam Khosroabadi, Lisa Batey, Desi Nicodemus, Council President Kathy Hyzy, and Mayor Mark Gamba

Staff Present: Kelly Brooks, Assistant City Manager; Justin Gericke, City Attorney; Jon Hennington, Equity Program Manager; Ann Ober, City Manager; Scott Stauffer, City Recorder; Luke Strait, Police Chief

Mayor Gamba called the meeting to order at 5:59 p.m.

1. CALL TO ORDER

A. Pledge of Allegiance.

B. Native Lands Acknowledgment.

2. ANNOUNCEMENTS

Mayor Gamba announced upcoming activities, including a heritage lecture, a housing needs survey, park planning meetings, and the city's Arbor Day activities. **Councilor Batey** noted a wetlands clean-up work party event.

3. PROCLAMATIONS AND AWARDS

A. Domestic Violence Awareness Month – Proclamation

Strait, **Gabriela Gomez**, and **Christy Ahlquist** with Clackamas Women's Services (CWS) introduced the proclamation and remarked on the services available to those in domestic violence situations. Council thanked CWS for the services they provide, and the group noted the process for requesting services. **Councilor Khosroabadi** remarked on personal experiences with domestic violence. **Mayor Gamba** proclaimed October to be Domestic Violence Awareness Month.

B. Indigenous Peoples Day – Proclamation

Hennington remarked on the history of recognizing Indigenous Peoples and noted Indigenous Day celebrations in the area. **Mayor Gamba** proclaimed October 10, 2022, to be Indigenous Peoples Day.

C. Hispanic Heritage Month – Proclamation

Hennington commented on the history of recognizing Hispanic, Latinx, Latino, and Latina cultures. **Mayor Gamba** proclaimed September 15 – October 15, 2022, to be Hispanic Heritage Month.

D. Energy Efficiency Day – Proclamation

Mayor Gamba discussed the importance of promoting energy efficient vehicles, buildings, and habits and proclaimed October 5, 2022, to be Energy Efficiency Day.

4. SPECIAL REPORTS

A. City Manager Updates – Report

Ober provided an update on the city's work to address houselessness, including the recruitment of a behavioral health specialist and a peer outreach coordinator, working with non-profit groups to provide services, looking at whether a shelter could be placed in the city, and drafting a camping ordinance.

Ober explained that Council needed to appoint a Council member to serve on the Clackamas County Water Environment Services (WES) Advisory Board. **Councilor Khosroabadi** expressed interest in serving on the board.

It was moved by Councilor Batey and seconded by Council President Hyzy to appointment Councilor Khosroabadi to the WES Advisory Board as the city's representative. Motion passed with the following vote: Councilors Khosroabadi, Batey, Nicodemus, and Hyzy and Mayor Gamba voting "aye." [5:0]

Ober noted that the city maintained a Rotary Club membership for Council members and reported that Councilor Khosroabadi had expressed interest in being a Rotary member. It was Council consensus that Khosroabadi should fill Council's Rotary Club membership. **Ober** noted staff would continue to attend Rotary meetings as well.

5. COMMUNITY COMMENTS

Mayor Gamba reviewed the public comment procedures and **Ober** reported that there was no follow-up report from the September 20 community comments. No audience member wished to address Council.

6. CONSENT AGENDA

It was moved by Council President Hyzy and seconded by Councilor Nicodemus to approve the Consent Agenda Items A. and B.

A. City Council Meeting Minutes:
   1. **September 6, 2022, Work Session, and**
   2. **September 6, 2022, Regular Session.**

B. ~~Authorization of a cooperative agreement with the North Clackamas Urban Watersheds Council (NCWC) for the Kellogg Creek Restoration and Community Enhancement Project.~~ (removed from the agenda)

C. An Oregon Liquor Control Commission (OLCC) application for Ohana Hawaiian Café, 10608 SE Main Street – Limited Off-Premises Sales.

Motion passed with the following vote: Councilors Khosroabadi, Batey, Nicodemus, and Hyzy and Mayor Gamba voting "aye." [5:0]

7. BUSINESS ITEMS

Mayor Gamba announced that an agenda item regarding climate action goals in Clackamas County had been added to the business items part of the agenda.

A. New City Hall Update – Report

Brooks provided an update on the work to prepare the new city hall building, including the timeline for awarding construction contracts and reviewing interior design and infrastructure details for the first-floor community room and staircase.

The group observed how many people could be seated in the new city hall community room and the plan to make sure the community room would not be an inactive store front. **Brooks** remarked on art elements planned for the new city hall building.

Brooks discussed a proposal to install a light wall in the staircase and **Council President Hyzy** expressed support for the light wall concept.

Brooks reviewed plans for the new city hall's third floor Council chambers and reported that due to Americans with Disabilities Act (ADA) requirements the dais could not be raised as originally designed. The group remarked on the audio and visual (AV) benefits of raising the dais and the challenges of raising the floor.

Brooks reported on plans to construct gender neutral restrooms on the third floor and presented chambers carpeting, wall, and paneling color schemes. **Mayor Gamba**, **Stauffer**, and **Brooks** remarked on plans for staff to consult AV experts on the layout and technical elements to be included in chambers. The group commented on pros and cons of how other board and Council chambers had been designed.

Brooks discussed plans to design exterior signage, parking security infrastructure, and staff locker rooms and showers in the basement at the new city hall. The group noted the planned uses of the new city hall's basement.

Stauffer reported on possible locations of the new city hall's flag poles.

Councilor Batey, **Brooks**, and **Council President Hyzy** remarked on whether the information kiosk at the current city hall would be relocated to the new city hall.

6. B. Authorization of a cooperative agreement with NCWC for the Kellogg Creek Restoration and Community Enhancement Project.

Councilor Batey asked what had delayed the agreement and **Brooks** reported that NCWC's attorney had not finished reviewing the agreement.

B. Equity Goal Update – Report

Hennington introduced Nicole Yates and Annette Humm Keen with Keen Independent Research (KIR) and reviewed the city's equity work over the last two years.

Yates and **Keen** reviewed the plan for the Milwaukie diversity, equity, and inclusion (DEI) study, noting KIR's approach to community outreach and inclusion.

Yates discussed the DEI study's goals and methodology, the plan to review current city policies, processes, and priorities, identify community needs, and how internal and external discussions would be approached. **Yates** noted how the study findings would be reported to Council and the public and reviewed the project timeline and next steps.

Councilor Batey and **Yates** noted a study website and **Hennington** reported that the public phase would be announced the week of October 10.

Council President Hyzy and **Hennington** observed that the DEI study would look at the work done by the city and that the community would be asked to participate in the study. **Mayor Gamba** suggested the DEI study be laid out in a way that clearly communicates how the city and community could make progress.

Hennington reviewed the timeline for when city and community surveys would go out. **Keen** commented on the importance of taking a wholistic view of DEI to set the city up to be a DEI leader. **Yates** noted that the study's findings would be broken into helpful categories making the document accessible. **Council President Hyzy** thanked Keen and Yates for setting-up a well-designed study.

Councilor Nicodemus underscored the importance of staff and community members internalizing the DEI study and committing to personally growing. **Keen** and **Hennington** agreed with Nicodemus and suggested equity work took a long time.

Countywide Climate Goals – Discussion (added to the agenda)

Mayor Gamba commented that one intention of the city's Climate Action Plan (CAP) work was to be a model for other cities and remarked that the following presentation was part of that intent.

Bill Street, unincorporated Clackamas County resident and Clackamas County Climate Action Task Force (CATF) member, remarked on the impact of climate change on daily life, commended Milwaukie for its climate leadership, and asked the city to encourage the county, state, and other cities to set similar climate goals.

Jenny Davies, unincorporated Clackamas County resident and CATF member, asked Council to consider a resolution to encourage other cities to adopt climate goals. **Davies** reviewed climate goals adopted by states, counties, and cities and presented information about the negative health effects of climate change.

Councilor Batey and **Council President Hyzy** asked about CATF's work. **Street** provided a summary of the CATF's work and the group remarked that some county leaders want the CATF to function slowly. **Council President Hyzy** encouraged Street and Davies to ask other cities to pursue adopting their own plans.

Councilor Khosroabadi remarked on the county's early interest in using Milwaukie's CAP as a model and asked if the county had done so. **Davies** and **Street** suggested many wanted their communities to be like Milwaukie and some had taken small steps toward that model without much accountability.

Mayor Gamba suggested Street and Davies could help draft a resolution for Council to consider adopting at a future meeting.

8. PUBLIC HEARING

A. None Scheduled.

9. COUNCIL REPORTS

Council President Hyzy commented on a survey from Metro on the regional transportation system plan and encouraged the public to participate.

10. ADJOURNMENT

It was moved by Councilor Nicodemus and seconded by Councilor Batey to adjourn the Regular Session. Motion passed with the following vote: Councilors Khosroabadi, Batey, Nicodemus, and Hyzy and Mayor Gamba voting "aye." [5:0]

Mayor Gamba adjourned the meeting at 8:21 p.m.

Respectfully submitted,

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Scott Stauffer, City Recorder

CITY OF MILWAUKIE

RS 6. C.
11/1/22

OCR USE ONLY

COUNCIL STAFF REPORT

To: Mayor and City Council
Ann Ober, City Manager

Date Written: Oct. 19, 2022

Reviewed: Brent Husher, Library Director

From: Scott Stauffer, City Recorder

Subject: **Library Board Appointment**

ACTION REQUESTED

As outlined in the Milwaukie Municipal Code (MMC), Council is asked to approve a resolution making an appointment to the Ledding Library Board.

HISTORY OF PRIOR ACTIONS AND DISCUSSIONS

In May 2022, the individual nominated to fill the vacant position participated in the city's annual board and committee (BC) interviews and was identified by the interview panel as an alternate candidate to fill future vacancies.

On October 5, Library Board position 4 became vacant when Robin Chedister resigned.

ANALYSIS

Authority to fill city board and committee (BC) vacancies is granted to the Mayor and Council by Section 26 of the City Charter. To fill vacant positions, members of Council along with appropriate staff liaisons and committee chairs recruit volunteers and usually conduct interviews from applications received by the city, however interviews are not required by the MMC. Appointed individuals serve for a term length determined by the MMC. Upon the completion of a term, if the individual is eligible, they may be reappointed by Council to serve another term.

Committee appointments are made when a term expires or when a position is vacated. All BC terms expire on June 30. Some committees have positions nominated by neighborhood district associations (NDAs) instead of by an interview panel. NDA-nominated appointments are noted.

Most BC positions are term-limited, meaning there is a limit to the number of times that members can be re-appointed. The nominated individual would be appointed to complete a term that has already started. The nominated individual would be eligible for reappointment to future terms.

The nominated individual was identified as an alternate appointee to the Library Board during the city's first annual BC recruitment process in May. Accordingly, when position 4 became vacant the nominated individual was at the top of the alternate list and has therefore been nominated to fill the vacant position.

Maryruth Storer has been nominated to fill Library Board position 4. Maryruth has lived in the city since 2017 and is a retired librarian with experience serving as chair of the American Association of Law Libraries (AALL) Executive Board and president of the Southern California Association of Law Libraries among several national library associations.

BUDGET, WORKLOAD, AND CLIMATE IMPACTS
There are no fiscal, workload, or climate impacts associated with the recommended actions.

COORDINATION, CONCURRENCE, OR DISSENT
Staff worked with Council members, the Library Board staff liaison, and chair, to conduct interviews in May 2022 and to confirm the nomination of the identified individual.

STAFF RECOMMENDATION
Staff recommends the following appointment:

Ledding Library Board: 2-year terms, limit of 3 consecutive terms.

Position	Name	Term Start Date	Term End Date
4	Maryruth Storer	11/1/2022	6/30/2023

ALTERNATIVES
Council could decline to make the recommended appointment which would result in a continued vacancy on the board.

ATTACHMENTS
1. Resolution

CITY OF MILWAUKIE

COUNCIL RESOLUTION No.

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MILWAUKIE, OREGON, MAKING APPOINTMENT AN APPOINTMENT TO THE LEDDING LIBRARY BOARD.

WHEREAS Milwaukie Charter Section 26 authorizes the Mayor, with the consent of the Council, to make appointments to boards and committees (BCs); and

WHEREAS the individual identified for appoint participated in the city's first annual BC recruitment and interview process and was identified as an alternate for future Library Board vacancies; and

WHEREAS a vacancy exists on the Ledding Library Board; and

WHEREAS staff recommends that the following individual who had been identified as an alternate for the Library Board, be appointed to fill the current board vacancy:

Ledding Library Board:

Position	Name	Term Start Date	Term End Date
4	Maryruth Storer	11/1/2022	6/30/2023

Now, Therefore, be it Resolved by the City Council of the City of Milwaukie, Oregon, that the individual named in this resolution is hereby appointed to the identified city board, committee, or commission for the term dates noted.

Introduced and adopted by the City Council on **November 1, 2022.**

This resolution is effective immediately.

Mark F. Gamba, Mayor

ATTEST: APPROVED AS TO FORM:

Scott S. Stauffer, City Recorder

Justin D. Gericke, City Attorney

RS Agenda Item 7

Business Items

CITY OF MILWAUKIE

RS 7. A.
11/1/22

OCR USE ONLY

COUNCIL STAFF REPORT

To: Mayor and City Council
Ann Ober, City Manager

Date Written: Oct. 20, 2022

Reviewed: Joseph Briglio, Community Development Director, and
Laura Weigel, Planning Manager

From: Brett Kelver, Senior Planner

Subject: **Annexation of Property at 5731 SE Laurel St**

ACTION REQUESTED

Council is asked to approve application A-2022-001, an annexation petition, and adopt the attached ordinance and associated findings in support of approval (Attachment 1). Approval of this application would result in the following actions:

- Annexation into the city of 5731 SE Laurel St (Tax Lot 1S2E30AD04400), the "annexation property."
- Application of a moderate density residential (MD) Comprehensive Plan land use designation and a moderate density residential (R-MD) zoning designation to the annexation property.
- Amendments to the city's Comprehensive Plan land use map and zoning map to reflect the city's new boundary and the annexation property's new land use and zoning designations.
- Withdrawal of the annexation property from the following urban service districts:
    - Clackamas County Service District for Enhanced Law Enforcement
    - Clackamas County Service District #5 for Street Lights

HISTORY OF PRIOR ACTIONS AND DISCUSSIONS

July 1990: Clackamas County Order No 90-726 established an urban growth management agreement (UGMA) in which the city and county agreed to coordinate the future delivery of services to the unincorporated areas of north Clackamas County. With respect to Dual Interest Area "A," the agreement states: "The city shall assume a lead role in providing urbanizing services."

January 2010: Council annexed the rights-of-way (ROW) in the Northeast Sewer Extension (NESE) project area making all properties in this area contiguous to the city limits and eligible for annexation (Ordinance 2010).

June 2010: Council approved the first annexation of property in the NESE project area (Ordinance 2016, land use file #A-10-01). Since then, Council has approved the annexation of approximately 167 additional properties in the NESE area. To date, there are approximately 92 properties within the NESE project area that have not yet annexed.

August 2022: The property owners at 5731 SE Laurel St approached the city's community development department to initiate the expedited annexation process and make an emergency connection to the city sewer system. The owners signed a consent to annex form and paid the necessary fees and charges.

ANALYSIS

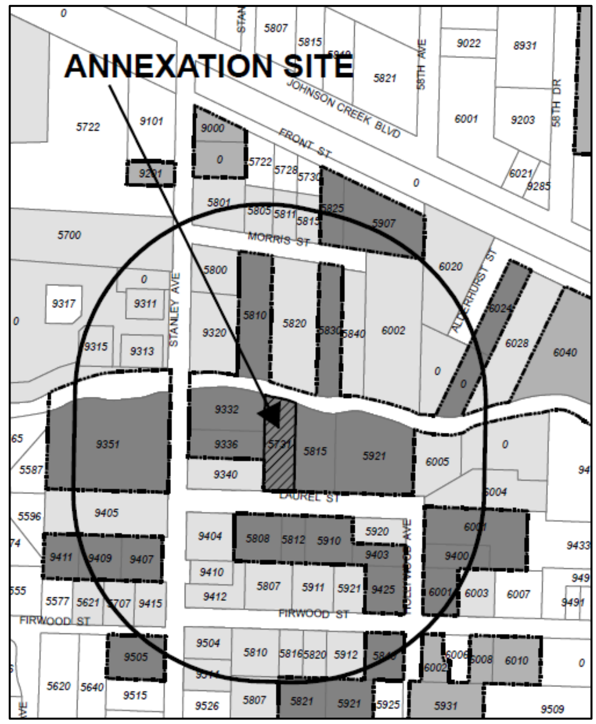
Proposal

The applicants, Britney Rodriguez and Darrin King, have applied to annex the approximately 12,500-sq-ft (0.29-acre) site to the city. The annexation property is developed with a single unit detached dwelling. It has residential Clackamas County land use and zoning designations and will receive equivalent residential city land use and zoning designations upon annexation.

Site and Vicinity

The annexation property is within the city's UGMA area and is contiguous to the existing city limits along the public right-of-way (ROW) of Laurel Street to the south and where adjacent to the neighboring property at 9340 SE Stanley Ave to the west (see Figure 1). The annexation property is currently developed with a single-unit house; the surrounding area consists primarily of other single-unit detached residential dwellings.

Figure 1. Site Map



Annexation Petition

The petition is being processed as an expedited annexation. Under the expedited process, a city land use and zoning designation is automatically applied to the annexation property upon annexation. Any property that is within the UGMA area and contiguous to the city boundary may apply for an expedited annexation so long as all property owners of the area to be annexed and at least 50% of registered voters within the area to be annexed consent to the annexation. Clackamas County has certified that these thresholds are met for the annexation property.

As set forth in Milwaukie Municipal Code (MMC) Table 19.1104.1.E, the expedited annexation process automatically assigns city land use and zoning designations to the annexation property based on the existing Clackamas County land use and zoning designations. The existing county Comprehensive Plan land use designation for the annexation property is low density residential (LDR), which corresponds to the city's moderate density (MD) Comprehensive Plan designation upon annexation. The current county zoning designation for the annexation property is urban low-density residential R-10, which corresponds to a city zoning designation of moderate density residential (R-MD) upon annexation.

Pursuant to city, regional, and state regulations on expedited annexations, all necessary parties, interested persons, and residents and property owners within 400 feet of the site were notified of these proceedings under MMC 19.1103.4.1.C. A public hearing is not required for an expedited annexation; however, Council must adopt an ordinance to implement the annexation.

Annexation Approval Criteria

The annexation application is subject to Milwaukie Comprehensive Plan Chapter 6 City Growth and Governmental Relationships, Oregon Revised Statutes (ORS) Chapter 222 City Boundary

Changes, Metro Code Chapter 3.09 Local Government Boundary Changes, and MMC Chapter 19.1100 Annexations and Boundary Changes.

Expedited annexations must meet the approval criteria of MMC 19.1102.3. Compliance with the applicable criteria is detailed in Attachment 1 (Exhibit A, Findings).

Utilities, Service Providers, and Service Districts

The city is authorized by ORS 222.120(5) to withdraw the annexation property from non-city service providers and districts upon annexation to the city. This allows for a more unified and efficient delivery of urban services to the newly annexed property and is in keeping with the city's Comprehensive Plan policies relating to annexation.

- Wastewater: The annexation property is within the city's sewer service area and, via an emergency connection allowed in conjunction with the proposed annexation, is served by the city's 8-inch sewer line accessible in Laurel Street.
- Water: The annexation property is currently served by Clackamas River Water (CRW) through CRW's existing water line in Laurel Street. Pursuant to the city's intergovernmental agreement (IGA) with CRW, water service will continue to be provided by CRW and the annexation property will not be withdrawn from this district at this time.
- Storm: The annexation property is not connected to a public stormwater system. Treatment and management of on-site stormwater will be required when new development occurs.
- Fire: The annexation property is currently served by Clackamas Fire District #1 and will continue to be served by this fire district upon annexation since the entire city is within this district.
- Police: The annexation property is currently served by the Clackamas County Sheriff's Office and is within the Clackamas County Service District for Enhanced Law Enforcement, which provides additional police protection to the area. The city has its own police department, and this department can adequately serve the site. To avoid duplication of services, the site will be withdrawn from this district upon annexation to the city.
- Street Lights: As of July 1, 2011, an IGA between the city and Clackamas County Service District No. 5 for Street Lights (the "district") transferred operational responsibility to the city for the street lights and street light payments in the city's NESE project area. The annexation property will be withdrawn from the district upon annexation to the city.
- Other Services: Community development, public works, planning, building, engineering, code enforcement, and other municipal services are available through the city and will be available to the site upon annexation. The annexation property will continue to receive services and remain within the boundaries of certain regional and county service providers, such as TriMet, North Clackamas School District, Vector Control District, and North Clackamas Parks and Recreation District.

BUDGET IMPACTS

This annexation will have minimal fiscal impact on the city. As with most annexations of residential properties, the costs of providing governmental services will likely be offset by the collection of property taxes. According to Clackamas County Assessor data, the total current assessed value of the annexation property is $170,835. Based on the latest information available (from the Clackamas County Rate Book for 2021), total property tax collection of approximately $3,094 is anticipated for the annexation property. The city will receive approximately $768 of this total.

WORKLOAD IMPACTS
For most city services, workload impacts from the annexation itself will be minimal and will likely include, but are not limited to, utility billing, provision of general governmental services, and the setting up and maintenance of property records.

CLIMATE IMPACTS
The annexation is not expected to have any impact on the climate. The property is currently occupied by a single-unit home and redevelopment is not anticipated in the short term.

COORDINATION, CONCURRENCE, OR DISSENT
All city departments, necessary parties, interested persons, and residents and property owners within 400 feet of the annexation property were notified of these proceedings as required by city, regional, and state regulations. The Lewelling Neighborhood District Association (NDA) also received notice of the annexation petition and the Council meeting.

The city did not receive comments from any necessary parties with objections to the proposed annexation.

STAFF RECOMMENDATION
Approve the application and adopt the ordinance and findings in support of approval.

ALTERNATIVES
Council has two decision-making options:

1. Approve the application and adopt the ordinance and findings in support of approval.
2. Deny the application and adopt findings in support of denial.

ATTACHMENTS
1. Annexation Ordinance
    Exhibit A. Findings in Support of Approval
    Exhibit B. Legal Description and Annexation Map
2. Annexation Site Map
3. Applicant's Annexation Application

CITY OF MILWAUKIE

COUNCIL ORDINANCE No.

AN ORDINANCE OF THE CITY OF MILWAUKIE, OREGON, ANNEXING A TRACT OF LAND IDENTIFIED AS TAX LOT 1S2E30AD04400 AND LOCATED AT 5731 SE LAUREL ST INTO THE CITY LIMITS OF THE CITY OF MILWAUKIE (FILE #A-2022-001).

WHEREAS the territory proposed for annexation is contiguous to the city's boundary and is within the city's urban growth management area (UGMA); and

WHEREAS the requirements of the Oregon Revised Statutes (ORS) for initiation of the annexation were met by providing written consent from a majority of electors and all owners of land within the territory proposed for annexation; and

WHEREAS the territory proposed for annexation lies within the territory of the Clackamas County Service District for Enhanced Law Enforcement and Clackamas County Service District #5 for Street Lights; and

WHEREAS the annexation and withdrawals are not contested by any necessary party; and

WHEREAS the annexation will promote the timely, orderly, and economic provision of public facilities and services; and

WHEREAS Table 19.1104.1.E of the Milwaukie Municipal Code (MMC) provides for the automatic application of city zoning and comprehensive plan land use designations; and

WHEREAS the city conducted a public meeting and mailed notice of the public meeting as required by law; and

WHEREAS the city prepared and made available an annexation report that addressed all applicable criteria, and, upon consideration of such report, the City Council favors annexation of the tract of land and withdrawal from all applicable districts based on findings and conclusions attached as Exhibit A.

Now, Therefore, the City of Milwaukie does ordain as follows:

Section 1. The Findings in Support of Approval attached as Exhibit A are adopted.

Section 2. The tract of land described and depicted in Exhibit B is annexed to the City of Milwaukie.

Section 3. The tract of land annexed by this ordinance and described in Section 2 is withdrawn from the Clackamas County Service District for Enhanced Law Enforcement and Clackamas County Service District #5 for Street Lights.

Section 4. The tract of land annexed by this ordinance and described in Section 2 is assigned a Comprehensive Plan land use designation of moderate density residential (MD) and a municipal code zoning designation of moderate density residential R-MD.

Section 5. The city will immediately file a copy of this ordinance with Metro and other agencies required by Metro Code Chapter 3.09.030, ORS 222.005, and ORS 222.177. The annexation and withdrawal will become effective upon filing of the annexation records with the Secretary of State as provided by ORS 222.180.

Read the first time on _________ and moved to second reading by _________ vote of the City Council.

Read the second time and adopted by the City Council on _________.

Signed by the Mayor on _________.

____
Mark F. Gamba, Mayor

ATTEST:	APPROVED AS TO FORM:
______________________________	______________________________
Scott S. Stauffer, City Recorder	Justin D. Gericke, City Attorney

EXHIBIT A

FINDINGS IN SUPPORT OF APPROVAL

Based on the staff report for the annexation of 5731 SE Laurel St, the "annexation property," the Milwaukie City Council finds:

1. The annexation property consists of one tax lot comprising 0.29 acres (tax lot 1S2E30AD04400). The annexation property is contiguous to the existing city limits along the public right-of-way (ROW) in Laurel Street to the south and where adjacent to the neighboring property at 9340 SE Stanley Ave to the west. The annexation property is within the regional urban growth boundary and also within the city's urban growth management area (UGMA).

   The annexation property is developed with a single-unit detached dwelling. The surrounding area consists primarily of single-unit detached dwellings.

2. The current owners of the annexation property seek annexation to the city to access city services, namely sewer service. The owners have signed a consent to annex form and paid the necessary fees and charges to allow an emergency connection to the city sewer service.

3. The annexation petition was initiated by consent of all owners of land on August 31, 2022, with an application for annexation submitted to the city on September 6, 2022. It meets the requirements for initiation set forth in ORS 222.125, Metro Code Section 3.09.040, and Milwaukie Municipal Code (MMC) Subsections 19.1104.1.A.3 and 19.1102.2.C.

4. The annexation petition was processed and public notice was provided in accordance with ORS Section 222.125, Metro Code Section 3.09.045, and MMC 19.1104. The annexation petition is being processed as an expedited annexation at the request of the property owner. It meets the expedited annexation procedural requirements set forth in MMC Section 19.1104.

5. The expedited annexation process provides for automatic application of city comprehensive plan land use and zoning designations to the annexation property based on their existing comprehensive plan land use and zoning designations in the county, which are urban low density residential (LDR) and residential R-10, respectively. Pursuant to MMC Table 19.1104.1.E, the automatic city comprehensive plan land use and zoning designations for the annexation property are both moderate density residential, MD and R-MD, respectively.

6. The applicable city approval criteria for expedited annexations are contained in MMC 19.1102.3. They are listed below with findings in italics.

   A. The subject site must be located within the city's urban growth boundary (UGB);

      The annexation property is within the regional UGB and within the city's UGMA.

B. The subject site must be contiguous to the existing city limits;

The annexation property is contiguous to the existing city limits along the public ROW of Laurel Street to the south and where adjacent to the neighboring property at 9340 SE Stanley Ave to the west.

C. The requirements of Oregon Revised Statutes for initiation of the annexation process must be met;

Britney Rodriguez and Darrin King, the current property owners, consented to the annexation by signing the petition. The current property owners are the only registered voters for the annexation property. As submitted, the annexation petition meets the Oregon Revised Statutes requirements for initiation pursuant to the "Consent of All Owners of Land" initiation method, which requires consent by all property owners and a majority of the electors, if any, residing in the annexation territory.

D. The proposal must be consistent with Milwaukie Comprehensive Plan policies;

Chapter 12 of the comprehensive plan contains the city's annexation policies. Applicable annexation policies include: (1) delivery of city services to annexing areas where the city has adequate services and (2) requiring annexation in order to receive a city service. With annexation, the city will take over urban service provision for the property. City services to be provided include wastewater collection, stormwater management, police protection, and general governmental services. As proposed, the annexation is consistent with Milwaukie Comprehensive Plan policies.

E. The proposal must comply with the criteria of Metro Code Sections 3.09.045(d) and, if applicable, (e).

The annexation proposal is consistent with applicable Metro code sections for expedited annexations as detailed in Finding 7.

F. The proposal must comply with the criteria of Section 19.902 for Zoning Map Amendments and Comprehensive Plan Map Amendments, if applicable.

The annexation would add new territory within the city limits, and the new territory must be designated on both the zoning map and the comprehensive plan map for land use. These additions effectively constitute amendments to the zoning and comprehensive plan land use maps.

The approval criteria for zoning map amendments and comprehensive plan amendments are provided in MMC 19.902.6.B and 19.902.4.B, respectively. Collectively, the criteria address issues such as compatibility with the surrounding area, being in the public interest and satisfying the public need, adequacy of public facilities, consistency with transportation system capacity, consistency with goals and policies of the Milwaukie Comprehensive Plan and relevant Metro plans and policies, and consistency with relevant State statutes and administrative rules.

MMC Table 19.1104.1.E establishes automatic zoning map and comprehensive plan land use map designations for expedited annexations. If a proposed designation is consistent with the table, it is consistent with the various applicable plans and policies.

In the case of the proposed annexation, the annexation property will assume the zoning and comprehensive plan designations provided in MMC Table 19.1104.1.E, which are R-MD and moderate density residential, respectively. The approval criteria for both proposed amendments are effectively met.

7. Prior to approving an expedited annexation, the city must apply the provisions contained in Section 3.09.045.D of the Metro Code. They are listed below with findings in italics.

   A. Find that the change is consistent with expressly applicable provisions in:

      (1) Any applicable urban service agreement adopted pursuant to ORS 195.065;

      There is one applicable urban service agreement adopted pursuant to ORS 195 in the area of the proposed annexation (see Finding 8, Street lights). The City has an UGMA agreement with Clackamas County that states that the City will take the lead in providing urban services in the area of the proposed annexation. The proposed annexation is in keeping with the city's policy of encouraging properties within the UGMA to annex to the city.

      The City has an intergovernmental agreement with Clackamas Water Environment Services (WES) regarding wholesale rates for wastewater treatment, but that agreement does not address issues related to annexations.

      (2) Any applicable annexation plan adopted pursuant to ORS 195.205;

      There are no applicable annexation plans adopted pursuant to ORS 195 in the area of the proposed annexation.

      (3) Any applicable cooperative planning agreement adopted pursuant to ORS 195.020 (2) between the affected entity and a necessary party;

      There are no applicable cooperative planning agreements adopted pursuant to ORS 195 in the area of the proposed annexation.

      (4) Any applicable public facility plan adopted pursuant to a statewide planning goal on public facilities and services;

      Clackamas County completed a North Clackamas Urban Area Public Facilities Plan in 1989 in compliance with Goal 11 of the Land Conservation and Development Commission for coordination of adequate public facilities and services. The city subsequently adopted this plan as an ancillary comprehensive plan document. The plan contains four elements:

      - *Sanitary Sewerage Services*
      - *Storm Drainage*
      - *Transportation Element*
      - *Water Systems*

      The proposed annexation is consistent with the four elements of this plan as follows:

      <u>Wastewater</u>*: The City is the identified sewer service provider in the area of the proposed annexation and maintains a public sewer system that can adequately serve the annexation property via an 8-inch sewer line accessible in Laurel Street.*

Storm: The annexation property is not connected to a public storm water system. Treatment and management of on-site storm water will be required when new development occurs.

Transportation: Access is provided to the annexation property via the public ROW of Laurel Street, a local street maintained by the city. The City may require public street improvements along the annexation property's frontage when new development occurs.

Water: Clackamas River Water (CRW) is the identified water service provider in this plan. However, the City's more recent UGMA agreement with the county identifies the City as the lead urban service provider in the area of the proposed annexation. The City's water service master plan for all of the territory within its UGMA addresses the need to prepare for future demand and coordinate service provision changes with CRW. As per the City's intergovernmental agreement (IGA) with CRW, CRW will continue to provide water service to the annexation property through its existing water line in Laurel Street.

(5) Any applicable comprehensive plan.

The proposed annexation is consistent with the Milwaukie Comprehensive Plan, which is more fully described on the previous pages. The Clackamas County Comprehensive Plan contains no specific language regarding city annexations. The comprehensive plans, however, contain the city-county UGMA agreement, which identifies the area of the proposed annexation as being within the city's UGMA. The UGMA agreement requires that the City notify the County of proposed annexations, which the City has done. The agreement also calls for City assumption of jurisdiction of local streets that are adjacent to newly annexed areas. The City has already annexed and taken jurisdiction of the public ROW in Laurel Street adjacent to the annexation property.

B. Consider whether the boundary change would:

(1) Promote the timely, orderly, and economic provision of public facilities and services;

With annexation, the City will be the primary urban service provider in the area of the proposed annexation, and the annexation will facilitate the timely, orderly, and economic provision of urban services to the annexation properties.

The City has public sewer service in this area in Laurel Street.

(2) Affect the quality and quantity of urban services; and

The annexation property consists of one tax lot developed with a single-unit detached dwelling. Annexation of the site is not expected to affect the quality or quantity of urban services in this area, given the surrounding level of urban development and the existing level of urban service provision in this area.

(3) Eliminate or avoid unnecessary duplication of facilities and services.

Upon annexation, the annexation property will be served by the Milwaukie Police Department. In order to avoid duplication of law enforcement services, the site will be *withdrawn from the Clackamas County Service District for Enhanced Law Enforcement upon annexation.*

8. The City is authorized by ORS Section 222.120(5) to withdraw annexed territory from non-City service providers and districts upon annexation of the territory to the city. This allows for more unified and efficient delivery of urban services to newly annexed properties and is in keeping with the City's comprehensive plan policies relating to annexation.

   Wastewater: The annexation property is within the City's sewer service area and, via an emergency connection allowed in conjunction with the proposed annexation, is served by the City's 8-inch sewer line accessible in Laurel Street.

   Water: The annexation property is currently served by CRW through CRW's existing water line in Laurel Street. Pursuant to the City's IGA with CRW, water service will continue to be provided by CRW and the annexation property will not be withdrawn from this district at this time.

   Storm: The annexation property is not connected to a public storm water system. Treatment and management of on-site storm water will be required when new development occurs.

   Fire: The annexation property is currently served by Clackamas Fire District #1 and will continue to be served by this fire district upon annexation, since the entire city is within this district.

   Police: The annexation property is currently served by the Clackamas County Sheriff's Department and is within the Clackamas County Service District for Enhanced Law Enforcement, which provides additional police protection to the area. The City has its own police department, and this department can adequately serve the site. In order to avoid duplication of services, the site will be withdrawn from this district upon annexation to the city.

   Street Lights: As of July 1, 2011, an intergovernmental agreement between the City and Clackamas County Service District No. 5 for Street Lights (the "District") transferred operational responsibility to the City for the street lights and street light payments in the City's northeast sewer extension project area. The annexation property will be withdrawn from the District upon annexation to the city.

   Other Services: Community development, public works, planning, building, engineering, code enforcement, and other municipal services are available through the City and will be available to the site upon annexation. The annexation property will continue to receive services and remain within the boundaries of certain regional and county service providers, such as TriMet, North Clackamas School District, Vector Control District, and North Clackamas Parks and Recreation District.

Exhibit A

Annexation to the City Of Milwaukie
LEGAL DESCRIPTION

Milwaukie Annexation File No. A-2022-001

Property Address: 5731 SE Laurel St, Milwaukie OR 97222

Tax Lot Description: 1S2E30AD04400

Legal Description: The East 40 feet of Lot 1, Block 1, HOLLYWOOD PARK, in the County of Clackamas and State of Oregon; ALSO, the West half of Lot 2, Block 1, HOLLYWOOD PARK, as determined by a line drawn parallel with and 25 feet distant Westerly from the Easterly line of said Lot.

Exhibit B

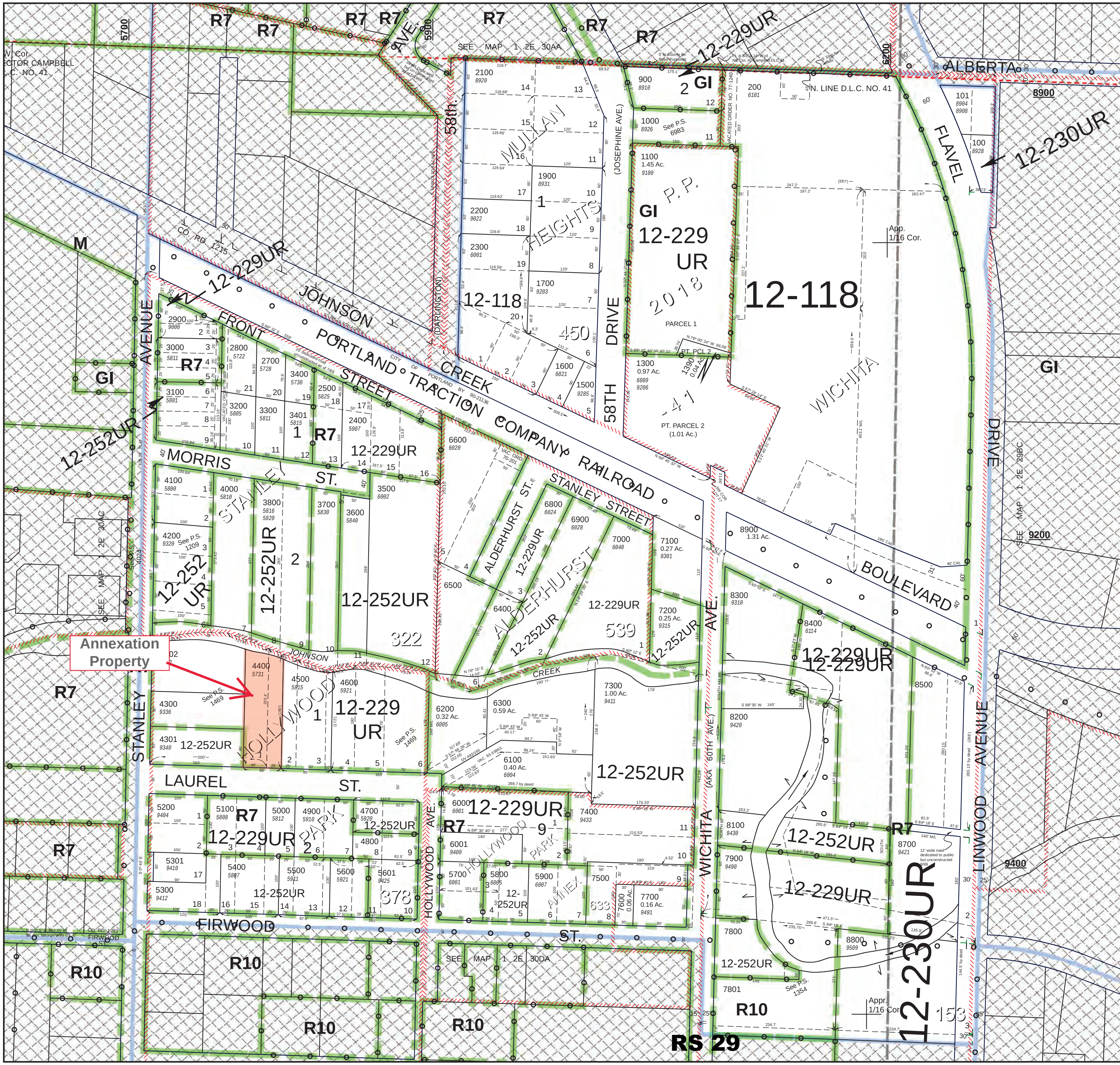
1 2 E 30AD

S.E.1/4 N.E.1/4 SEC.30 T.1S. R.2E. W.M.

CLACKAMAS COUNTY

1" = 100'

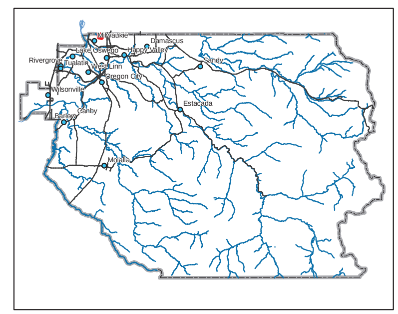
D. L. C.
HECTOR CAMPBELL NO. 41



Cancelled Taxlots

201
202
300
400
500
600
700
800
1200
1400
1490
1800
2000
2190
2600
3900
6700
7701
8000
8600

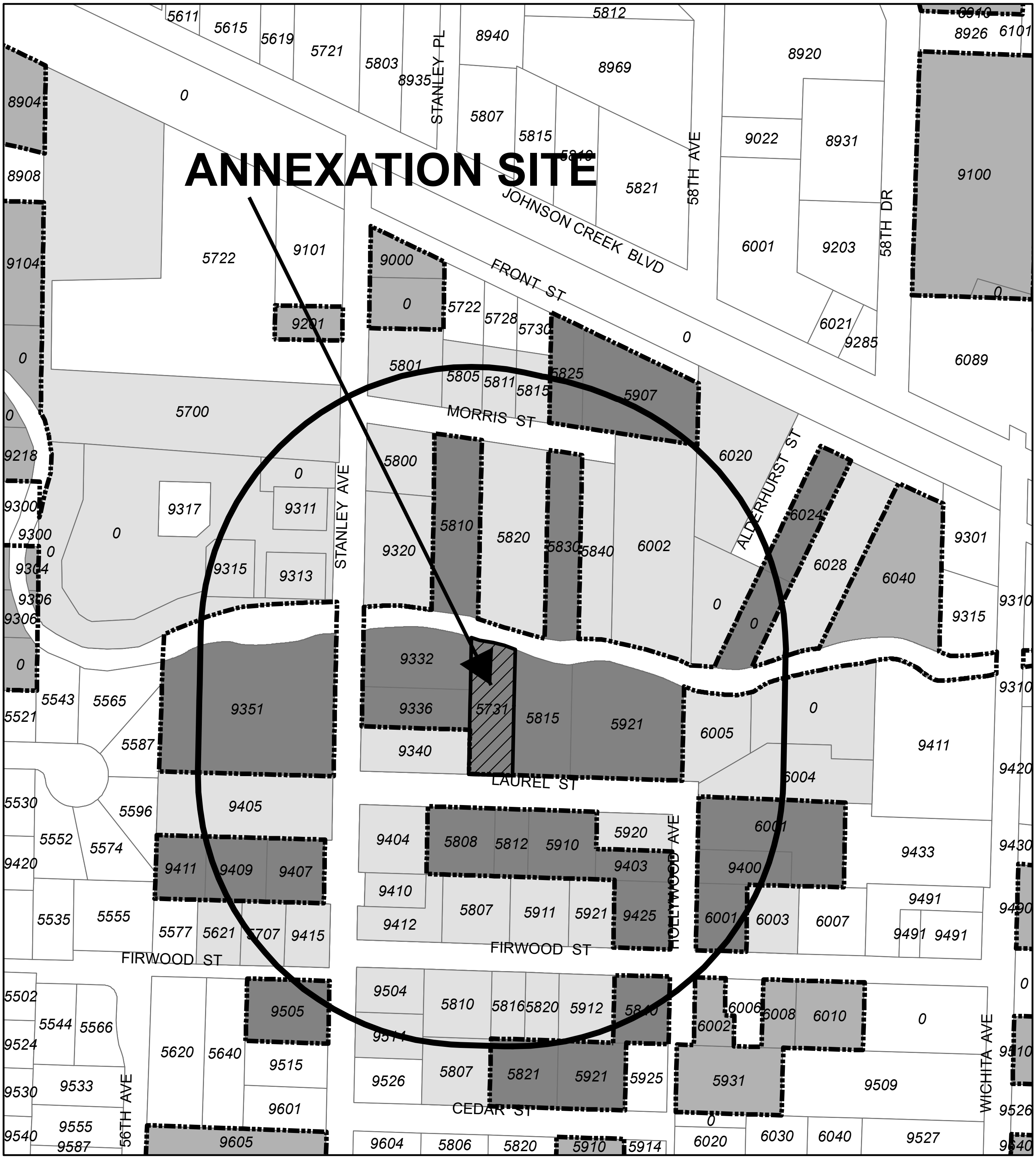
Parcel Boundary
Private Road ROW
Historical Boundary
Railroad Centerline
Tax Code Lines
Map Index
Water Lines
Land Use Zoning
Plats
Water
Corner
Section Corner
1/16th Line
Govt Lot Line
DLC Line
Meander Line
PLSS Section Line
Historic Corridor 40'
Historic Corridor 20'



THIS MAP IS FOR ASSESSMENT PURPOSES ONLY

3/22/2022

1 2 E 30AD



Site Map
5731 SE Laurel St
(Tax ID = 1S2E30AD, lot 04400)
File #A-2022-001

Legend

- A-2022-001 site
- 400-ft public notice boundary
- City Limit
- Properties receiving notice (Milwaukie)
- Other tax lots (Milwaukie)
- Properties receiving notice (unincorporated)
- Other tax lots (unincorporated)

North

0 62.5 125 250 375 500 Feet

RS 30

MILWAUKIE PLANNING
6101 SE Johnson Creek Blvd
Milwaukie OR 97206
503.786.7630
planning@milwaukieoregon.gov

Expedited Annexation Application

File # A-2022-001

RESPONSIBLE PARTIES:

APPLICANT (owner or other eligible applicant): Britney Rodriguez & Darrin King	
Mailing address: 5731 SE Laurel Street, Milwuakie OR	Zip: 97222
Phone(s): 971-216-9311, 503-866-1573	Email: britneycrodriguez7@gmail.com
APPLICANT'S REPRESENTATIVE (if different than above): Tami Liesy	
Mailing address: 919 NE 19th Ave Suite 100	Zip: 97232
Phone(s): 503-388-1881	Email: tami@realestateportland.com

SITE INFORMATION:

Address(es): 5731 SE Laurel St, Milw OR 97222	Map & Tax Lot(s): 12E30AD/04400	
Existing County zoning: R-7	Proposed City zoning: R-MD	Property size: 12,720.00 Sq Ft
Existing County land use designation: LDR	Proposed City land use designation: MD	

PROPOSAL (describe briefly):

Decommission current cesspool and hook up the city main.

LIST OF ALL CURRENT UTILITY PROVIDERS:

Check all that apply (do not list water or sewer service providers)

Cable, internet, and/or phone:	☐ Comcast		☐ CenturyLink
Energy:	☒ PGE		☒ NW Natural Gas
Garbage hauler:	☐ Waste Management		☒ Hoodview Disposal and Recycling
	☐ Wichita Sanitary	☐ Oak Grove Disposal	☐ Clackamas Garbage
☐ **Other (please list):**			

SIGNATURE:

ATTEST: I am the property owner, or I am eligible to initiate this application per Milwaukie Municipal Code (MMC) Subsection 19.1001.6.A. I have attached all owners' and voters' authorizations to submit this application. I understand that uses or structures that were not legally established in the County are not made legal upon annexation to the City. To the best of my knowledge, the information provided within this application package is complete and accurate.

Submitted by: [signature] Date: 9/6/2022

CONTINUED ON REVERSE

RESET

THIS SECTION FOR OFFICE USE ONLY:

File #: A-2022-001 Fee: $ 150- Receipt #: Recd. by:	Date stamp:
Associated application file #'s:	RECEIVED SEP 06 2022 CITY OF MILWAUKIE PLANNING DEPARTMENT
Neighborhood District Association(s): Lewelling NDA	
Notes (include discount if any):	

EXPEDITED ANNEXATION
PETITION OF OWNERS OF 100% OF LAND AREA AND PETITION OF AT LEAST 50% OF REGISTERED VOTERS

TO: The Council of the City of Milwaukie, Oregon

RE: Petition for Annexation to the City of Milwaukie, Oregon

We, the petitioners (listed on reverse), are property owners of and/or registered voters in the territory described below. We hereby petition for, and give our consent to, annexation of this territory to the City of Milwaukie.

This petition includes a request for the City to assign a zoning and land use designation to the territory that is based on the territory's current zoning designation in the County, pursuant to the City's expedited annexation process.

The territory to be annexed is described as follows:

(Insert legal description below OR attach it as Exhibit "A")

The East 40 feet of Lot 1 Block 1, HOLLYWOOD PARK, in the County of Clackamas and State of Oregon, ALSO, the West half of Lot 2, Block 1, HOLLYWOOD PARK, as determined by a line drawn parallel with and 25 feet distant Westerly from the Easterly line of said Lot

AUG 2022
RECEIVED
CLACKAMAS
COUNTY
ASSESSOR
MN

PETITION SIGNERS

NOTE: This petition may be signed by qualified persons even though they may not know their property description or voter precinct number.

*PO = Property Owner RV = Registered Voter OV = Owner and Registered Voter

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE
[signature]	Darrin D King			x	8/31/2022

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #
5731 SE Laurel St, Milw OR 97222	1S	2E	30AD	4400 ~~182~~	420

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE
Britney Rodriguez	Britney C Rodgiguez			x	8/31/2022

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #
5731 SE Laurel St, Milw OR 97222	1S	2E	30AD	4400 ~~182~~	420

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #

SIGNATURE	PRINTED NAME	I AM A:* PO	RV	OV	DATE

PROPERTY ADDRESS	TOWNSHIP	RANGE	¼ SEC.	LOT #(S)	VOTER PRECINCT #

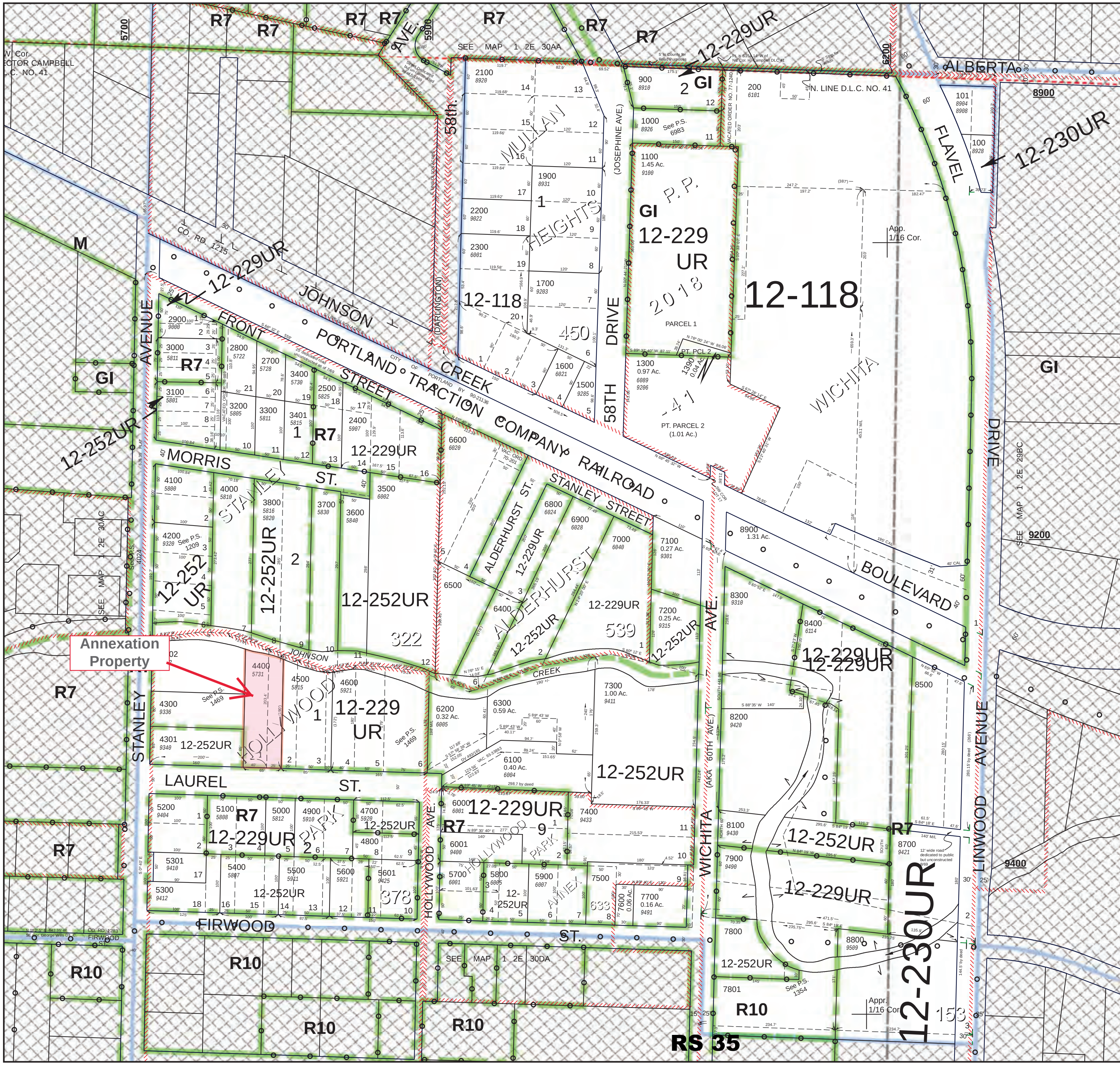


Exhibit B

1 2 E 30AD

S.E.1/4 N.E.1/4 SEC.30 T.1S. R.2E. W.M.

CLACKAMAS COUNTY

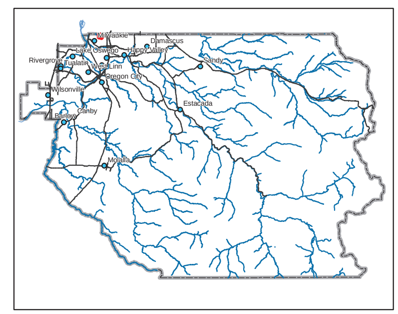
1" = 100'

D. L. C.
HECTOR CAMPBELL NO. 41

Cancelled Taxlots

201
202
300
400
500
600
700
800
1200
1400
1490
1800
2000
2190
2600
3900
6700
7701
8000
8600

- Parcel Boundary
- Private Road ROW
- Historical Boundary
- Railroad Centerline
- Tax Code Lines
- Map Index
- Water Lines
- Land Use Zoning
- Plats
- Water
- Corner
- Section Corner
- 1/16th Line
- Govt Lot Line
- DLC Line
- Meander Line
- PLSS Section Line
- Historic Corridor 40'
- Historic Corridor 20'



THIS MAP IS FOR ASSESSMENT PURPOSES ONLY

3/22/2022

1 2 E 30AD

CERTIFICATION OF PROPERTY OWNERSHIP OF 100% OF LAND AREA

I hereby certify that the attached petition contains the names of the owners[1] (as shown on the last available complete assessment roll) of 100% of the land area of the territory proposed for annexation as described in the attached petition.

Name Mary Neigel

Title GIS Cartographer 2

Department Assessment + Tax

County of Clackamas

Date August 31, 2022

MN

[1] Owner means the legal owner of record or, where there is a recorded land contract which is in force, the purchaser thereunder. If a parcel of land has multiple owners, each consenting owner shall be counted as a percentage of their ownership interest in the land. That same percentage shall be applied to the parcel's land mass and assessed value for purposes of the consent petition. If a corporation owns land in territory proposed to be annexed, the corporation shall be considered the individual owner of that land.

CERTIFICATION OF LEGAL DESCRIPTION AND MAP

I hereby certify that the description of the territory included within the attached petition (located on Assessor's Map 1 2E 30 AD) has been checked by me. It is a true and exact description of the territory under consideration and corresponds to the attached map indicating the territory under consideration.

Name Mary Neigel

Title GIS Cartographer 2

Department Assessment + Tax

County of Clackamas

Date August 31, 2022

2022 RECEIVED CLACKAMAS COUNTY ASSESSOR

MN

CERTIFICATION OF REGISTERED VOTERS

I hereby certify that the attached petition contains the names of at least 50% of the electors registered in the territory proposed for annexation as described in the attached petition.

Name Jennifer Wessels

Title Senior Elections Specialist

Department Elections

County of Clackamas

Date 9-6-22

CERTIFIED COPY OF THE ORIGINAL
SHERRY HALL, COUNTY CLERK

BY:

NOTICE LIST

(This form is NOT the petition)

LIST THE NAMES AND ADDRESSES OF ALL PROPERTY OWNERS AND REGISTERED VOTERS IN THE TERRITORY PROPOSED FOR ANNEXATION.

	Name of Owner/Voter	Mailing Street Address / Mailing City/State/Zip	Property Address / Property Description (township, range, ¼ section, and tax lot)
1	Darrin David King (signature)	5731 SE Laurel St	5731 SE Laurel St. (Milwaukie)
		Milw. OR 97222	1S2E30AD04400
2	Britney C. Rodriguez (signature: Britney Rodriguez)	5731 SE Laurel St	5731 SE Laurel St. (Milwaukie)
		Milw. OR 97222	1S2E30AD04400
3			
4			
5			
6			
7			
8			
9			
10			

EXPEDITED ANNEXATION CODE EXCERPTS

MILWAUKIE MUNICIPAL CODE SECTIONS

19.1104.1 Expedited Process

A. A petition for any type of minor boundary change may be processed through an expedited process as provided by Metro Code Chapter 3.09.

5. Approval criteria for annexations are found in subsection 19.1102.3.

19.1102.3 Annexation Approval Criteria. The city council shall approve or deny an annexation proposal based on findings and conclusions addressing the following criteria.

A. The subject site must be located within the city urban growth boundary;

B. The subject site must be contiguous to the existing city limits;

C. The requirements of the Oregon Revised Statutes for initiation of the annexation process must be met;

D. The proposal must be consistent with Milwaukie comprehensive plan policies;

E. The proposal must comply with the criteria of Metro Code Sections 3.09.050(d) and, if applicable, (e).

F. The proposal must comply with the criteria of Section 19.902 for Zoning Map Amendments and Comprehensive Plan Map Amendments, if applicable.

METRO CODE SECTIONS

3.09.050 Hearing & Decision Requirements for Decisions Other Than Expedited Decisions.

(d) To approve a boundary change, the reviewing entity shall apply the criteria and consider the factors set forth in subsections (d) and (e) of Section 3.09.045.

MILWAUKIE COMPREHENSIVE PLAN

Chapter 6: City Growth and Governmental Relationships; City Growth Element

Goal Statement: To identify the City's future planning and service area, establish the respective responsibilities for reviewing and coordinating land use regulations and actions within the area, and determine the most cost-effective means to provide the full range of urban services within the area.

Applicant Response

The proposal meets the applicable requirements listed above.

X ______________________________

(Applicant's Signature)

CITY OF MILWAUKIE

RS 7. B.
11/1/22

OCR USE ONLY

COUNCIL STAFF REPORT

To: Mayor and City Council
Ann Ober, City Manager

Date Written: Oct. 20, 2022

Reviewed: Peter Passarelli, Public Works Director

From: Natalie Rogers, Climate & Natural Resource Manager

Subject: **Building Energy Decarbonization Resolutions**

ACTION REQUESTED

Council is asked to provide direction to staff on the proposed building energy decarbonization resolutions(s).

HISTORY OF PRIOR ACTIONS AND DISCUSSIONS

January 18, 2022: Mayor Gamba introduced a resolution directing city staff to develop code which would require new construction to be electric-only, develop a roadmap to decarbonization of existing buildings and require electrification of city building purchased and renovated exceeding established thresholds.

July 12: Council heard informational presentations from NW Natural Gas and Climate Solutions on the topics of methane gas, utility services, climate goals, and gas-related impacts.

September 6: Council discussed three separate resolutions addressing building carbon emission reduction and city climate goals, including a resolution establishing requirements for city-owned and city-financed buildings to be systematically decarbonized, a resolution directing city exploration of programming to assist in the voluntary decarbonization of existing buildings, and a resolution for the city to develop an ordinance to accelerate new construction decarbonization by implementing a ban on natural gas (also known as methane gas) as a fuel source for new construction. Council heard testimony and directed staff to return with staff recommendations on each resolution.

ANALYSIS

Milwaukie's Climate Action Plan (CAP) and declared climate emergency establish community goals calling for carbon-free electricity by 2030, zero-emissions from building fuels by 2035, and community carbon neutrality by 2045. In the last five years staff have created, expanded, and promoted a variety of building carbon reduction programs and projects with direction from City Council and the CAP. Further reductions are needed to meet Milwaukie's climate goals as building energy remains in the top two emission sectors for the community. Regulation of fuels available for building energy to prioritize carbon-free energy options is a potential strategy to significantly reduce emissions in the community.

This report is provided to address the three resolutions proposed by Council and includes staff response to Council's questions and requests for staff for each resolution. To provide context and reference information for Council and community discussion, staff have also prepared a general overview on building energy and fuels in relation to climate impacts.

For clarity of discussion, staff will refer to 'natural gas' as 'methane gas' in this report, as they are the same product and the term 'methane gas' encompasses multiple products offered by the gas utility with different marketing but the same chemical makeup and emissions when used in buildings.

Relevant Background Information

Energy utility providers control the investment, procurement, and product design for their respective energy products. The emissions, affordability, and other values of each energy type influences city strategies to achieve adopted climate goals. Cities can influence energy emissions in their community through regulation, advocacy, and programming. Utilities can work with cities to align emission reduction targets and partner to offer goal-aligned products and programs.

Electricity Utility Emission Goals

The path Oregon electric utilities are on towards decarbonization aligns with regional climate goals but is slower than Milwaukie's goals. Oregon investor-owned electric utilities are mandated by Oregon House Bill (HB) 2021 to achieve 100% decarbonized electricity by 2040 through banning siting of new generation facilities that use fossil fuels and requiring generation from carbon-free technologies and programs. Prior to HB 2021, Portland General Electric (PGE) held similar internal decarbonization goals and timelines and contributed to the HB 2021's development and adoption[1]. PGE intends to meet state requirements through strategic retirement of methane gas-powered generation facilities, investment in carbon-free generation facilities, energy efficiency and time of use programming and incentives.

Methane 'Natural' Gas Utility Emission Goals

Methane gas, also called 'natural gas', is a fossil fuel that produces emissions at the time of consumption when the gas is burned for energy generation. NW Natural Gas has internal 'voluntary' carbon reduction goals of reaching 30% 'carbon savings' by 2035 and carbon neutrality by 2050[2]. Oregon's Climate Protection Program (CPP), administered by the Oregon Department of Environmental Quality (DEQ) in response to Executive Order 20-04, established statewide emission reduction goals of 50% reduction from 1990 levels by 2035 and 90% by 2050 through emission caps for a variety of industries, including methane gas utilities. NW Natural and two other Oregon methane gas utilities oppose the adopted regulations and have filed suit to prevent the CPP from moving forward[3]. NW Natural states that the utility can reach their 2050 goal without CPP requirements through offsets, re-captured methane gas, and 'demand-side activities' such as energy efficient technologies and behaviors[2]. NW Natural also intends to use 'clean' or 'low-carbon' hydrogen in their future resource mix.

Renewable Natural Gas and Hydrogen Gas

NW Natural utilizes re-captured methane gas, marketed and regulated as 'renewable natural gas' (RNG), in their carbon reduction strategies to reduce product emissions. RNG can be considered more favorable than other methane gas products in some contexts, as it is created through the re-capture of methane biproducts of biosolids and waste processing, including

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1 OPB, (May 25, 2021), '*Oregon's big climate bill of 2021 generates little friction*'

2 NW Natural (2021), *Vision 2050: Destination Zero*

3 OPB, (March 20, 2022), *'Businesses challenge Oregon's new climate program in court'*

wastewater treatment, landfills, and anaerobic digesters used in agricultural industries. 'Renewable Thermal Certificates' can be purchased by utility customers and retired by the utility to fund development of new RNG projects in exchange for carbon offsets for the customer. While RNG is produced in a different process than other methane products, it is chemically identical to the 'fossil-fuel' methane gas and produces equivalent emissions at time of consumption. Current RNG production and supply is low, and the cost of RNG project development makes the product less affordable than other available fuel types. Regional energy stakeholders including the Citizens Utility Board (CUB) predict that NW Natural will not obtain the volume of RNG required to reach their goal-driven forecasted scenarios, and that the volume and expense of RNG procurement required to reach the utility's 2050 goal will create an unaffordable utility product for customers[4].

Hydrogen fuels could be a potential carbon-free fuels product for utilities and customers if created through electrolysis (the splitting of water into hydrogen and oxygen molecules) using carbon-free electricity. Hydrogen gas can also be created using carbon emitting electricity or natural gas systems, which would result in further fuel associated emissions. Gas utilities could also mix hydrogen fuels with methane gas to lower carbon intensity of products, however recent studies have shown a potential increase in other pollutants even though carbon emissions decline[5] Hydrogen fuel technology is not currently affordable nor accessible in Oregon, though recent legislation directed Oregon Department of Energy to conduct a study on the benefits and barriers to renewable hydrogen, which is expected to be presented by November 15.

Additional Gas-Powered Technologies and Electrification Considerations

Electric assets and technologies have quickly accelerated in development and market availability and have seen significant efficiency improvements which can compete or outpace gas alternatives. Concerns over electricity power outages may influence installation of electricity or gas equipment as customers perceive resiliency benefits of gas technologies, though it should be noted that many gas technologies require electricity as well to function or to operate safely. Electric utilities and technology developers are addressing resiliency concerns by diversifying electricity generation technologies, modernizing distribution systems, and creating and investing in battery storage technologies for grid-wide and building specific power backups.

Aging and/or leaking methane gas building appliances have been shown to negatively impact air quality beyond established healthy indoor and outdoor limits, particularly in homes with old or unmaintained gas appliances and poor ventilation[6]. Air quality concerns from methane use has been an argument in favor of electrification, particularly if vulnerable communities such as children or elders, or lower income residents with barriers to appliance or housing improvements are prioritized for programming. Environmental justice communities have also highlighted the necessity of substantial electrification programs to be available for these communities to ensure a just transition and to avoid a situation where the low-income or other vulnerable communities are the remaining gas utility customers and resource financers.

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[4] Citizens Utility Board, (May 20, 2022), *'What is Renewable Natural Gas?'*

[5] Natural Gas Intelligence, (Oct 4, 2022), 'New York Hydrogen-Natural Gas Blending Study Offers Mixed Results to Cut Emissions'

[6] RMI, (2020), Indoor Air Pollution: the Link Between Climate and Health

RESOLUTION ADDRESSING DECARBONIZATION OF CITY-OWNED AND CITY-FINANCED BUILDINGS

This resolution (Attachment 1) establishes electrification requirements for city-owned or city-financed building for the following circumstances:

- The city finances a building and expends $50,000 or more.
- The city performs major renovations and expends $50,000 or more on the renovation.
- The city donates a property with an appraised value of $50,000 or more.
- The city sells a city-owned property and the difference between the appraised value and sale price is $50,000 or more.

The draft resolution states that public buildings offering key community services may be permitted to maintain non-electric generators for backup purposes. The draft resolution directs the city to perform an inventory of facilities for retrofit opportunities to remove fossil fuel powered assets and prioritize electrification where possible. Using the inventory and available data, City staff are to prepare a feasibility study by January 1, 2025.

At the September 6 regular session, staff were asked to provide a high-level evaluation of electrification costs for existing city-owned buildings. The table below shows 2022 order of magnitude cost estimates for electrification retrofits:

BUILDING RETROFIT:	2022 ESTIMATE:
CITY HALL	**$683,000***
Required electrical upgrades	Unknown
Electric boiler installation	$375,000
Fan coil replacement and heat pump installation (x14), reuse heating water coils	$308,000
40TH AND HARVEY CAMPUS	**$200,000**
Required electrical service updates	Unknown
Electric boiler installation	$125,000
Install wall mount mini split units for primary heating and cooling (x5)	$75,000
PUBLIC SAFETY BUILDING**	**$313,000***
Required electrical service upgrades	Unknown
Remove gas boiler for warm up on VAV RTUs	$3,000
Replace existing single zone gas fired RTUs with heat pumps (x5)	$160,000
Install electric unit heaters in garage and shop	$150,000
ADVANTIS BUILDING	**$250,000***
Install new RTU heat pump	$250,000

BUILDING RETROFIT:	2022 ESTIMATE:
JOHNSON CREEK CAMPUS	**$428,000***
JC – Front Building	
Install new heat pumps to replace existing gas fired split systems (x4)	$160,000
Install new electric bay heaters (x5)	$100,000
JC – Public Works Operations	
Install heat pumps to replace gas fired split systems (x5)	$128,000
JC – Pole Barn	
Replace gas UH with electric option (x1)	$10,000
JC – Sign Shop	
Replace 1 gas UH with mini split heat pump	$30,000
MILWAUKIE CENTER	**$448,000***
Replace gas fired split systems with heat pumps (x10)	$448,000
Replace existing single zone gas fired RTU with heat pumps (x4)	
ALL BUILDING RETROFITS ***Service upgrades not included in cost estimates**	**$2,322,000**

*** Existing backup generators may need to be upgraded to handle full building electrification. Additional coordination with PGE will be necessary to ensure appropriate service upgrades and potential distribution infrastructure requirements are met to meet capacity.*

Staff Response

Staff believes that the draft resolution commitment of producing a feasibility report for city facility electrification is obtainable if the deadline is extended to June 30, 2024.

For this discussion, building energy-consuming assets are building assets which use a fuel source to operate and contribute to building energy sector emissions, including but not limited to heating, ventilation, and air-conditioning (HVAC), space heaters, boilers, and water heaters. Staff recommend that windows, building insulation, and other building features which impact energy efficiency and usage are excluded. Staff also recommend that the resolution references emission-free assets which can be defined as assets that emit no greenhouse gas emissions as a biproduct of operation.

Staff's proposed language on operational retrofit requirements for Council consideration is:

- Retrofits of all existing building fossil fuel-consuming assets with emission-free assets are required when:
    - When the system has lost functionality at the required level and repair is not an option.
    - The city finances a building and invests $500,000 or more in the transaction.
    - The city performs major renovations resulting in expenditure of $200,000 or more.
    - If building energy-consuming assets are already scoped for replacement in the renovation, emission-free assets must be prioritized for replacement options.
    - The city donates a property with an appraised market value of $500,000 or more.
    - The city sells a city-owned property and the difference between the appraised value and sale price is $200,000 or more.
    - The above requirements are to be implemented at the next budget cycle starting July 1, 2024, to allow for budgetary planning and to avoid violation of existing development agreements and contracts.
- If the city must invest in the repair of a building energy-consuming asset to restore asset functionality or the cost of the repair and/or associated continuing servicing to maintain functionality over the remaining expected lifetime of the asset exceeds 50% of the value of the asset, replacement of the asset with emission-free asset alternatives must be evaluated and performed if feasible.
    - The above requirement is to be implemented at the next budget cycle starting July 1, 2024, to allow for budgetary planning.
- The city manager may request approval from Council to exempt or delay retrofit requirements. Any exemption or extension granted by the Council will be narrowly tailored to maximize decarbonization efforts within given cost constraints. If equivalent emission-free asset options would cost 10% or more than fossil fuel-based alternatives, or if the established retrofitting requirements are determined by staff to be infeasible and/or prevent the project from proceeding, Council may approve the following actions:
    - Obtain a full exemption from performing required retrofit actions or receive a partial exemption to exclude specific asset replacements required. Partial

exemption requests must show that the city considered emission reduction potential when prioritizing asset replacement and determining which assets to exclude.
  - Receive an extension to allow for asset replacement at future defined date.

RESOLUTION SUPPORTING CITY-LED DECARBONIZATION INITIATIVES FOR EXISTING BUILDINGS

This resolution (Attachment 2) directs staff to explore voluntary building decarbonization programs and incentives for the community to choose to participate in. The resolution also directs staff to create a building decarbonization strategic plan to assess emission reduction timelines, programmatic requirements, and goal progress.

From staff perspective, the deliverables required by the existing buildings resolution are achievable and align with current city climate efforts. CAP updates can be designed to call out building-energy specific programming actions and metrics in more detail for community reporting purposes, or to address requirements established in the voluntary programming for existing buildings resolution (Attachment 2). They can also include emission reduction forecasting and back casting to develop more detailed goal timelines.

The draft existing building resolution also calls for building decarbonization specific community engagement to determine interests and impactful program offerings, and an existing building decarbonization roadmap to establish goals and strategies for the voluntary transition of existing buildings to emission-free assets by June 30, 2024. This could be achieved, especially if resources for this engagement, reporting and strategy development were provided through the draft climate fund. The climate fund could also be used to develop programs of interest identified in through engagement. This would fulfill the resolution mandate and align with Council direction on climate fund programming to maximize community values, including economic value and environmental justice, along with emissions reductions goals in program development.

Community feedback, particularly from underserved communities, would be essential in designing building decarbonization programs that could be utilized by all audiences while providing measurable emission reductions and positive community experiences. The below programs are initial strategies to address voluntary decarbonization needs for existing buildings which could be adjusted or expanded to meet community needs:

- Weatherization programs for low-income communities and residents in energy inefficient housing types such as mobile homes or aging rental units.
- Discounted or free heat pump installations for low-income community members.
- City-provided loans for qualified community members to reduce barriers of participation in federal inflation act rebate programs.
- Informational dashboards consolidating incentives, rebates, and energy bill reduction strategies and state utility assistance resources.
- Staff assistance in project development and grant applications for community groups
- Creation of a resource hub for commercial and industrial customers, including climate action materials geared towards employee outreach and education.
- Increased relationship building with large energy consumers in Milwaukie

If using climate fund resources for this work, Council will need to provide direction to staff on programming and project priorities, particularly if resources are to be allocated to other climate-related sectors like transportation and land use, or to pay for legal consult or building upgrades associated with the other building decarbonization resolutions addressed in this report.

RESOLUTION TO ACCELERATE DECARBONIZATION OF NEW CONSTRUCTION BUILDINGS

This resolution (Attachment 3) would prohibit buildings that are constructed after an established date from connecting to methane gas distribution systems to mitigate public health impacts and emission impacts. This mandate would not apply to existing buildings, and existing buildings can choose to keep their gas line connections and assets.

Regional conversations around methane gas bans have increased in prevalence as cities adopt climate goals and emission reduction targets which require the phase out of emission-intensive fossil fuels. Fuels neutrality requirements at the state level and with Energy Trust of Oregon means that existing incentives and programming cannot favor climate-friendly fuels and state stakeholders are prevented from offering fuels transition opportunities from methane gas to electricity, which offers better emission reduction potential. Oregon's state building code also preempts local jurisdictions from modifying building code based on community interests without an intensive and generally prohibitive local amendment process. These barriers have slowed Oregon community's adoption of building fossil fuel bans for new construction, while Washington, California and other less restricted states have seen numerous city fossil fuel regulations.

Regional Learnings

Recently, some cities have been looking at ways to implement a building fossil fuel ban for new construction by adopting code language that does not encroach state building code but instead addresses jurisdictional local rule over community design and right of way infrastructure. The City of Eugene has been exploring their own methane natural gas ban following dissolving discussions around NW Natural's franchise agreement with the city. Eugene staff are working with the Good Company to evaluate emission reduction potential in the community through a methane natural gas ban for new construction. Eugene City Council recently adopted four resolutions associated with the methane natural gas ban at their July 27, 2022 session, directing staff to draft ordinance language requiring new residential construction be all electric by June 1, 2023, directing the city manager to continue conversations with council on commercial and industrial customers, directing the city manager to bring a revision to their climate action plan to formalize their electrification goals, and directing the city manager to bring a proposal in the fall for engaging the community on decarbonization of existing buildings.

Milwaukie staff have reached out to Eugene, who offered to share the draft ordinance language once published ahead of their next council meeting on November 15. In general, Eugene's methane natural gas ban will restrict the hookup of new construction to gas utility infrastructure through code additions in their environment and health code chapter where their climate recovery code and other environmental compliance codes are located. Eugene staff did discuss this pathway with staff at the state Buildings Code Division (BCD) and shared that BCD staff did not have immediate concerns about the initial code concepts conflicting with the state building code preemption. Conflict could occur if the regulations attempted to influence the hookup abilities within the building itself, such as allowing fireplace hookups but not stove hookups. Eugene has not determined what city departments would 'own' the program if adopted and has not discussed in detail the expected financial and staff resource needs to run and enforce the program.

Eugene is planning on further engagement with commercial and industrial gas customers before proceeding with drafting ordinances establishing regulations for those building types. Staff are bringing an 'infeasibility waiver' to council on November 15 which could allow exemptions from the ban.

Staff Response

Staff recommend that Milwaukie waits to see what code language Eugene staff present to their Council and consider applicability for Milwaukie's use to meet the draft resolution requirements. A similar phased approach could be taken in Milwaukie to ensure engagement opportunities for commercial and industrial customers, with established deadlines for reporting back to council for continued discussions. The resources required to perform this work and address engagement needs, legal challenge, and supplemental programs could be significant. This could also be a use of potential climate fund revenue; however, it may reduce or exhaust funds for other programs, and council direction on prioritization would be required to balance competing program objectives and limited staff time.

BUDGET IMPACT

Climate fund revenue could supplement or cover the costs of these initiatives. Each resolution has individual resource needs to account for staff time, materials, technical guidance, and program development and implementation. Based on Council interests, the climate fund could be considered as a resource for this work, but prioritization of current and potential programming would need to occur to balance fund resources and staff time.

WORKLOAD IMPACT

Implementation of actions called for in these resolutions could impact the workloads of a variety of staff at the city, including public works staff, code compliance, building, and planning staff. Use of climate funds to bring on additional staff or contract out for assistance could reduce the staff workload associated with some items. Until further discussion on Council priorities and next steps in code adoption and program implementation (including expectations for engagement, enforcement, and other key program elements) occur, it will remain difficult for staff to estimate the potential or scale of impact on workload.

CLIMATE IMPACT

The resolutions each have significant carbon reduction potential which is needed to reach Milwaukie's climate goals. The programs, regulations, and upgrades addressed in these resolutions could reduce emissions in a challenging sector to address at the local scale and provide valuable livability and economic value to the community.

COORDINATION, CONCURRENCE, OR DISSENT

City staff continue to coordinate with regional governments and authorities on these efforts. Engagement efforts with local utility customers, utility providers, and advocates will occur through these discussions with council.

STAFF RECOMMENDATION

Staff recommends that Council discuss each resolution and provide direction on next steps.

ALTERNATIVES
None.

ATTACHMENTS
1. Draft Resolution Addressing City-Owned and -Financed Buildings
2. Draft Resolution Supporting Decarbonization of Existing Buildings
3. Draft Resolution Accelerating the Decarbonization of New Buildings

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MILWAUKIE, OREGON TO DECARBONIZE THE BUILDING SECTOR AND TO ACCELERATE THE TRANSITION TO ALL-ELECTRIC CITY-OWNED AND CITY-FINANCED BUILDINGS TO PROMOTE CLIMATE, PUBLIC HEALTH, AND RESILIENCY BENEFITS

WHEREAS, climate change is an existential crisis posing one of the most serious threats to the existence of humanity and all species on the planet; a threat that intersects and compounds multiple other crises facing humanity and our Earth; and

WHEREAS, the 11th United Nations Intergovernmental Panel on Climate Change ("IPCC") report from October 2018 states that we must cut greenhouse gas emissions in half by 2030 to limit global warming and avoid a climate catastrophe;[1] and

WHEREAS, in 2021, the United States and other leading economies agreed to the Global Methane Pledge to reduce methane emissions 30 percent by 2030;[2] and

WHEREAS, in Oregon, homes and buildings are the second highest source of Oregon's greenhouse gas emissions;[3] and

WHEREAS, the transportation and combustion of "natural" methane gas creates significant harms to public health and safety;[4] and

WHEREAS, leaks during the production, processing, transmission and distribution of "natural" methane gas are substantial,[5] releasing a potent greenhouse gas with approximately 86 times the global warming potential of carbon dioxide over a 20-year period;[6] and

WHEREAS, methane gas stoves emit hazardous air pollutants such as nitrogen dioxide and carbon monoxide, which compromise indoor air quality and the respiratory health of vulnerable populations, including low-income households, children, the elderly, and those with existing health conditions; and

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[1] See, e.g., IPCC report: 'now or never' if world is to stave off climate disaster | Climate crisis | The Guardian.

[2] See Joint US-EU Press Release on the Global Methane Pledge - The White House.

[3] See Figure 5 at State of Oregon: Energy in Oregon - Greenhouse Gas Emissions Data.

[4] See, e.g., "Methane Gas: Health, Safety, and Decarbonization" at Methane Gas: Health, Safety, and Decarbonization (powerpastfrackedgas.org); See also US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), "Gas Distribution Significant Incidents 20 Year Trend," (data as of July 12, 2021). Available at: https://portal.phmsa.dot.gov/analytics/saw.dll?Portalpages&PortalPath=%2Fshared%2FPDM%20Public%20Website%2F_portal%2FSC%20Incident%20Trend&Page=Significant; See also Oregon & Washington Physicians for Social Responsibility, "Fracked Gas Infrastructure: A Threat to Healthy Communities," (2019). Available at: https://www.oregonpsr.org/fracked_gas_a_threat_to_healthy_communities;

[5] See, e.g., Assessment of methane emissions from the U.S. oil and gas supply chain | Science (quantifying methane leaks in the gas supply chain and finding that in 2015, supply chain emissions were ~60% higher than the U.S. Environmental Protection Agency inventory estimate).

[6] See Methane is like 'CO2 on Steroids' When It Comes to Trapping Heat (sightline.org) (Citing IPCC 2018 Report WG1AR5_Chapter08_FINAL.pdf (ipcc.ch) at 731).

WHEREAS, children who grow up in homes with methane gas cooking appliances have a 42% higher risk of asthma symptoms;[7] and

WHEREAS, methane gas for heating in buildings leads to increases in outdoor air pollution;[8] and

WHEREAS, historically marginalized communities including low-income and Black, Indigenous and people of color (BIPOC) households are disproportionately impacted by outdoor air pollution;[9] and

WHEREAS, methane gas pipelines are prone to leaks and explosions and endanger the health and safety of communities;[10] and

WHEREAS, methane gas infrastructure poses a significant threat to Oregon residents in the event of a major earthquake;[11] and

WHEREAS, "renewable natural" methane gas still poses the same health and safety risks to communities as traditional "natural" gas;[12] and

WHEREAS, NW Natural, the state's largest methane gas utility which serves Milwaukie customers, is expected to cumulatively increase bills approximately 42 percent between October 2021 and November 2022;[13] and

WHEREAS, gas utility ratepayers are at significant risk of incurring additional costs and rate increases due to methane gas price volatility and utility business practices;[14] and

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[7] See Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children | International Journal of Epidemiology | Oxford Academic (oup.com).

[8] See Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California – Center for Occupational & Environmental Health (ucla.edu).

[9] See Air pollution exposure disparities across US population and income groups | Nature; See also Low-income, black neighborhoods still hit hard by air pollution -- ScienceDaily.

[10] See, e.g., Ahrens, M. and Evarts, B., "Natural Gas and Propane Fires, Explosions and Leaks Estimates and Incident Description," National Fire Protection Association Research (NFPA), (October 2018). Available at: https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Hazardo us-materials/osNaturalGasPropaneFires.ashx.

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[13] See Natural Gas Prices Are Going Up Before Winter | Blog | News | Oregon CUB.

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WHEREAS, in 2021, Oregon passed HB 2021, which sets milestones for electric utilities to transition to 100% clean electricity by 2040;[15] and

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WHEREAS, in 2020, the city declared a climate emergency and accelerated the goals in the Climate Action Plan by five years which made them: carbon-free electricity powering the city by 2030; net zero emissions from all buildings by 2035; carbon neutral city by 2045; and

WHEREAS, in 2022, the United States passed the Inflation Reduction Act, which among other things, will provide billions of dollars to homeowners and businesses for increasing energy efficiency and installing high-efficiency electric appliances like heat pumps;[16] and

WHEREAS, electric heat pumps provide both heating and cooling while providing significant operational greenhouse gas reduction benefits compared to gas furnaces;[17] and

WHEREAS, electrification will improve indoor air quality and overall health, by eliminating natural gas combustion inside homes that produces harmful indoor air pollution;[18] and

WHEREAS, electrification is widely recognized as a powerful strategy to address both climate change and poor air quality in frontline communities most vulnerable to climate impacts;[19] and

WHEREAS, every new building constructed with high-efficiency electric appliances will have climate, public health, and cost savings benefits for decades to come;[20] and

WHEREAS, the city has the opportunity to lead by example to make decisive, transformative, and sustainable changes in its municipal energy consumption, and can significantly lower the city's greenhouse gas emissions and overall carbon impact; and

WHEREAS, citywide, rapidly reducing methane gas use in buildings will help achieve Milwaukie's Community Climate Action Plan targets, and such actions will also improve public health and increase the quality of life throughout the city.

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[15] HB2021 2021 Regular Session - Oregon Legislative Information System (oregonlegislature.gov).

[16] See, e.g., https://www.forbes.com/sites/energyinnovation/2022/08/30/inflation-reduction-act-benefits-millions-of-efficient-electrified-buildings/.

[17] See Heat Pumps: A Path to Health and Climate Benefits - Energy Foundation; see also Rapid Electric Heat Transition Will Save Oregon $1.7 Billion, Report Finds - DeSmog.

[18] See, e.g., Eight Benefits of Building Electrification for Households, Communities, and Climate - RMI.

[19] See, e.g., Equitable Building Electrification: A Framework for Powering Resilient Communities (greenlining.org).

[20] See, e.g., The New Economics of Electrifying Buildings - RMI.

NOW, THEREFORE, BE IT RESOLVED BY THE COUNCIL OF THE CITY OF MILWAUKIE, that the City of Milwaukie recognizes the global and local benefits of decarbonizing homes and buildings and accelerating the transition to all-electric homes and buildings throughout the city; and be it

FURTHER RESOLVED as follows**:**

Resolution – Electrify City-Owned and City-Financed Buildings

Section 1. The City Manager is directed to require all new City-owned and City-financed[21] buildings and major renovations[22] of existing City-owned and City-financed buildings are built all-electric. In the event the cost of such actions would be 10% more expensive than using fossil fuel based alternatives, the City Manager may seek an exemption from taking such actions from the City Council. Any exemption granted by the City Council shall be narrowly tailored to maximize decarbonization efforts within given cost constraints. **Public buildings, which offer key services to the community, such as City Hall, may be permitted to maintain non-electric emergency generators.** This policy will become effective September 10, 2022.

Section 2. The City Manager is directed to inventory City-owned facilities that currently use fossil fuels and evaluate the feasibility of retrofitting those facilities to cease using fossil fuels, with a priority of electrification where feasible. The inventory and evaluation will make use of existing reports and data to prepare preliminary feasibility recommendations by **January 1, 2025**.

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[21] City-financed buildings are those receiving City funds of $50,000 or more, a donation of property with an appraised value of $50,000 or more, or a sale of city-owned property where the difference between the appraised value and sale price is $50,000 or more.
[22] As defined in Oregon statute.

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MILWAUKIE, OREGON TO DECARBONIZE THE BUILDING SECTOR AND TO ACCELERATE THE TRANSITION TO ALL-ELECTRIC EXISTING BUILDINGS TO PROMOTE CLIMATE, PUBLIC HEALTH, AND RESILIENCY BENEFITS

WHEREAS, climate change is an existential crisis posing one of the most serious threats to the existence of humanity and all species on the planet; a threat that intersects and compounds multiple other crises facing humanity and our Earth; and

WHEREAS, the 11th United Nations Intergovernmental Panel on Climate Change ("IPCC") report from October 2018 states that we must cut greenhouse gas emissions in half by 2030 to limit global warming and avoid a climate catastrophe;[1] and

WHEREAS, in 2021, the United States and other leading economies agreed to the Global Methane Pledge to reduce methane emissions 30 percent by 2030;[2] and

WHEREAS, in Oregon, homes and buildings are the second highest source of Oregon's greenhouse gas emissions;[3] and

WHEREAS, the transportation and combustion of "natural" methane gas creates significant harms to public health and safety;[4] and

WHEREAS, leaks during the production, processing, transmission and distribution of "natural" methane gas are substantial,[5] releasing a potent greenhouse gas with approximately 86 times the global warming potential of carbon dioxide over a 20-year period;[6] and

WHEREAS, methane gas stoves emit hazardous air pollutants such as nitrogen dioxide and carbon monoxide, which compromise indoor air quality and the respiratory health of vulnerable populations, including low-income households, children, the elderly, and those with existing health conditions; and

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[1] See, e.g., IPCC report: 'now or never' if world is to stave off climate disaster | Climate crisis | The Guardian.

[2] See Joint US-EU Press Release on the Global Methane Pledge - The White House.

[3] See Figure 5 at State of Oregon: Energy in Oregon - Greenhouse Gas Emissions Data.

[4] See, e.g., "Methane Gas: Health, Safety, and Decarbonization" at Methane Gas: Health, Safety, and Decarbonization (powerpastfrackedgas.org); See also US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), "Gas Distribution Significant Incidents 20 Year Trend," (data as of July 12, 2021). Available at: https://portal.phmsa.dot.gov/analytics/saw.dll?Portalpages&PortalPath=%2Fshared%2FPDM%20Public%20Website%2F_portal%2FSC%20Incident%20Trend&Page=Significant; See also Oregon & Washington Physicians for Social Responsibility, "Fracked Gas Infrastructure: A Threat to Healthy Communities," (2019). Available at: https://www.oregonpsr.org/fracked_gas_a_threat_to_healthy_communities;

[5] See, e.g., Assessment of methane emissions from the U.S. oil and gas supply chain | Science (quantifying methane leaks in the gas supply chain and finding that in 2015, supply chain emissions were ~60% higher than the U.S. Environmental Protection Agency inventory estimate).

[6] See Methane is like 'CO2 on Steroids' When It Comes to Trapping Heat (sightline.org) (Citing IPCC 2018 Report WG1AR5_Chapter08_FINAL.pdf (ipcc.ch) at 731).

WHEREAS, children who grow up in homes with methane gas cooking appliances have a 42% higher risk of asthma symptoms;[7] and

WHEREAS, methane gas for heating in buildings leads to increases in outdoor air pollution;[8] and

WHEREAS, historically marginalized communities including low-income and Black, Indigenous and people of color (BIPOC) households are disproportionately impacted by outdoor air pollution;[9] and

WHEREAS, methane gas pipelines are prone to leaks and explosions and endanger the health and safety of communities;[10] and

WHEREAS, methane gas infrastructure poses a significant threat to Oregon residents in the event of a major earthquake;[11] and

WHEREAS, "renewable natural" methane gas still poses the same health and safety risks to communities as traditional "natural" gas;[12] and

WHEREAS, NW Natural, the state's largest methane gas utility which serves Milwaukie customers, is expected to cumulatively increase bills approximately 42 percent between October 2021 and November 2022;[13] and

WHEREAS, gas utility ratepayers are at significant risk of incurring additional costs and rate increases due to methane gas price volatility and utility business practices;[14] and

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WHEREAS, the city has the opportunity to lead by example to make decisive, transformative, and sustainable changes in its municipal energy consumption, and can significantly lower the city's greenhouse gas emissions and overall carbon impact; and

WHEREAS, citywide, rapidly reducing methane gas use in buildings will help achieve Milwaukie's Community Climate Action Plan targets, and such actions will also improve public health and increase the quality of life throughout the city.

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NOW, THEREFORE, BE IT RESOLVED BY THE COUNCIL OF THE CITY OF MILWAUKIE, that the City of Milwaukie recognizes the global and local benefits of decarbonizing homes and buildings and accelerating the transition to all-electric homes and buildings throughout the city; and be it

FURTHER RESOLVED as follows**:**

Resolution – Electrify existing homes and buildings

Section 1. The City Manager and staff are directed to include efforts to decarbonize existing homes and buildings over time as a priority in any future Climate Action Plan updates. Such efforts shall include attempts to educate home and building owners about the benefits of decarbonizing buildings, including new high efficiency electric appliances, as well as any federal, state and local incentives and resources to finance such decarbonization efforts.

Section 2. Direct city manager to return to council with a proposal for engaging the community in developing a plan for decarbonizing buildings that has at its foundation social, environmental, and economic equity with emphasis on engagement of historically marginalized communities and their representatives.

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MILWAUKIE, OREGON TO DECARBONIZE THE BUILDING SECTOR AND TO ACCELERATE ALL-ELECTRIC FUTURE BUILDINGS TO PROMOTE CLIMATE, PUBLIC HEALTH, AND RESILIENCY BENEFITS

WHEREAS, climate change is an existential crisis posing one of the most serious threats to the existence of humanity and all species on the planet; a threat that intersects and compounds multiple other crises facing humanity and our Earth; and

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[19] See, e.g., Equitable Building Electrification: A Framework for Powering Resilient Communities (greenlining.org).

[20] See, e.g., The New Economics of Electrifying Buildings - RMI.

WHEREAS, a city may "Determine by contract or prescribe by ordinance or otherwise, the terms and conditions, including payment of charges and fees, upon which any public utility, electric cooperative, people's utility district or heating company, or Oregon Community Power, may be permitted to occupy the streets, highways or other public property within such city and exclude or eject any public utility or heating company therefrom.";[21]

NOW, THEREFORE, BE IT RESOLVED BY THE COUNCIL OF THE CITY OF MILWAUKIE, that the City of Milwaukie recognizes the global and local benefits of decarbonizing homes and buildings and accelerating the transition to all-electric homes and buildings throughout the city; and be it

FURTHER RESOLVED as follows**:**

Resolution – Decarbonize future homes and buildings

Section 1. The city staff are directed to develop code changes or take other actions, as necessary, to achieve the following outcome: Fuel gas piping, defined as conveying natural gas, manufactured gas, liquefied petroleum gas or mixtures of these gases, is prohibited from connecting to any building after February 15, 2024.

[21] ORS § 221.420(2)(a).

RS 7. B. 11/1/22 Presentation

CITY OF MILWAUKIE

Building Energy Resolution Discussion

November 1, 2022

Natalie Rogers
Climate and Natural Resource Manager

Peter Passarelli
Public Works Director

None of the resolutions or programs require existing residential or commercial gas customers to change <u>anything</u>.

Timeline

- Oct 2018 – CAP Adopted
- Jan 2020 – Climate Emergency Declaration
  - By 2035, net-zero emissions from building fuels
- Jan 2022 – First introduction of building energy resolutions
- July 2022 – Informational presentation from NW Natural and Climate Solutions
- Sept 2022 – Three separate resolutions introduced
  - City-owned building requirements for retrofits/upgrades
  - Existing buildings voluntary programs and strategies
  - New Construction mandates

Terms and Definitions

Decarbonization : the reduction in carbon dioxide emissions.

Carbon-free energy: Energy that creates no emissions when it is generated (electricity) or used or consumed (other fuels)

Electrification: The transition from fossil fuels to electricity

"Green" Hydrogen: hydrogen gas produced from electrolysis of water using carbon-free electricity

"Blue" Hydrogen: hydrogen gas produced from methane gas, steam and another catalyst

Methane/Natural Gas: Interchangeable terms. Natural gas is a marketing term for methane gas product.

Renewable Natural Gas: A methane gas product that is collected as a biproduct of approved biosolids processing. Equivalent chemical composition and emissions as non-renewable gas products.

RTU – Roof Top Unit

City-owned Buildings

As drafted:

- Establishes decarbonization requirements over time or with triggering event
  - Building purchase/renovations/donation/sale
  - Threshold ~$50k
- Directs staff to perform a feasibility study by Jan 1, 2024

Staff response:

- City-owned building estimate ~$2.32M
  - Service upgrade cost TBD
- Recommendation to increase thresholds
  - $200k reno, $500k sale/purchase
  - If repair >50% asset value, pursue electrification
  - July 1, 2024 effective date
- Schedule feasibility deadline by June 30, 2024

Question: donation of buildings?

BUILDING:	2022 ESTIMATE:
CITY HALL	**$683,000***
40TH AND HARVEY CAMPUS	**$200,000**
PUBLIC SAFETY BUILDING**	**$313,000***
ADVANTIS BUILDING	**$250,000***
JOHNSON CREEK CAMPUS	**$428,000***
JC – Front Building	$260k
JC – PW Operations	$128k
JC – Pole Barn	$10k
JC – Sign Shop	$30k
MILWAUKIE CENTER	**$448,000***
***Service upgrades required**	

Existing Buildings

VOLUNTARY ONLY! No requirements for existing buildings to change!

As drafted:

- Incentivizes and promotes <u>voluntary</u> electrification programs
  - From discussion: programs should have economic value
- **No requirements for existing buildings to change**
- Directs staff to develop strategic plan and timeline

Staff response:

- Similar goals and programs called for in existing CAP
- Community engagement to tailor programs to audiences needed
- Focus on weatherization, resiliency and economic incentives would provide benefits to many community members, address largest emitters
- Climate fund essential in being able to offer these programs

New-Construction Buildings

As drafted:

- Recognizes benefits of building decarbonization/electrification
- Prevents new-construction buildings from connecting to fuel-gas infrastructure by February 15, 2024

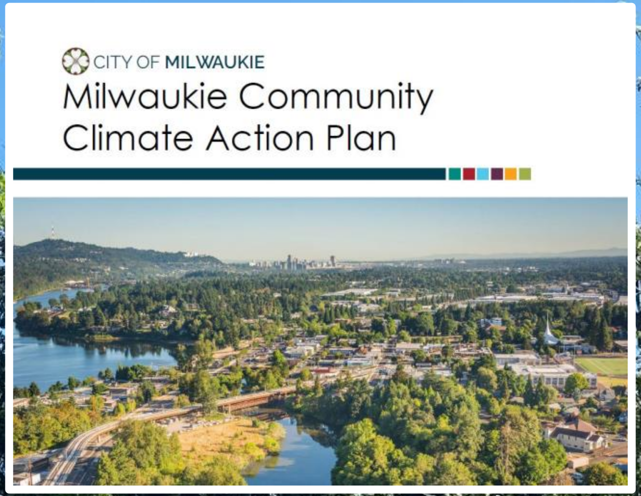
Staff response:

- City of Eugene staff presenting code language at Eugene 11/15 Council Session
  - Low-rise residential buildings
  - Phased approach for commercial/industrial w/ more engagement
  - Wait to see what language is presented
- Legal/code unknowns, potential costs
  - Climate funds could be used but need to balance other programming

Interested in learning more?
Milwaukieclimateaction.com

Thank you!

Natalie Rogers
503-786-7668
RogersN@milwaukieoregon.gov



CITY OF MILWAUKIE

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CITY COUNCIL

10722 SE Main Street
P) 503-786-7502
F) 503-653-2444
ocr@milwaukieoregon.gov

Speaker Registration

The City of Milwaukie encourages all citizens to express their views to their city leaders in a **respectful** and **appropriate** manner. If you wish to speak before the City Council, fill out this card and hand it to the City Recorder. Note that this Speakers Registration card, once submitted to the City Recorder, becomes part of the public record.

Name: Laura Edmonds

Organization: North Clackamas Chamber

Address:

Phone: 503-654-7777

Email: laura@yourchamber.com

Meeting Date: ______________ **Topic:** ______________

Agenda Item You Wish to Speak to:

- ☐ #4 Audience Participation
- ☐ #5 Public Hearing, Topic:
- ☐ #6 Other Business, Topic:

7B - New Bldg Energy & Climate

You are Speaking…

- ☐ in Support
- ☒ in Opposition
- ☐ from a Neutral Position
- ☐ to ask a Question

Comments:

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Name: Alma Pinto

Organization: Community Energy Project

Address: 12010 SE 21st Ave.
Phone: 954-523-9848
Email: alma@communityenergyproject.com

Meeting Date: 11/1/22 **Topic:**

Agenda Item You Wish to Speak to:

- ☐ #4 Audience Participation
- ☐ #5 Public Hearing, Topic:
- ☑ #6 Other Business, Topic: New Building to Energy Climate

You are Speaking…

- ☑ in Support
- ☐ in Opposition
- ☐ from a Neutral Position
- ☐ to ask a Question

Comments:

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Name: ANNE PERNICK

Address: 4630 SE MITCHELL ST. PORTLAND, OR 97206

Organization: SAFE CITIES at stand.earth

Phone: 541-390-8516

Email: anne@stand.earth

Meeting Date: 11/1/22

Topic: BUILDING ELECTRIFICATION

Agenda Item You Wish to Speak to:

- [ ] #4 Audience Participation
- [ ] #5 Public Hearing, Topic:
- [x] #6 Other Business, Topic: BUILDINGS, CLIMATE & ENERGY

You are Speaking…

- [x] in Support of all 3 resolutions
- [ ] in Opposition
- [ ] from a Neutral Position
- [ ] to ask a Question

Comments:

CITY OF MILWAUKIE
CITY COUNCIL

10722 SE Main Street
P) 503-786-7502
F) 503-653-2444
ocr@milwaukieoregon.gov

Speaker Registration

The City of Milwaukie encourages all citizens to express their views to their city leaders in a **respectful** and **appropriate** manner. If you wish to speak before the City Council, fill out this card and hand it to the City Recorder. Note that this Speakers Registration card, once submitted to the City Recorder, becomes part of the public record.

Name: XANTHIA WOLLAND

Address: 13615 SE KUEHN RD. MILWAUKIE OR 97222

Organization: OREGON ENVIRONMENTAL COUNCIL

Phone: 707.287.6845

Email: xanthia.wolland@gmail.com

Meeting Date: 11/1/22 **Topic:** BUILDINGS / CLIMATE

Agenda Item You Wish to Speak to:

- ☐ #4 Audience Participation
- ☐ #5 Public Hearing, Topic:
- ☒ #6 Other Business, Topic: BUILDINGS / ENERGY

You are Speaking...

- ☒ in Support
- ☐ in Opposition
- ☐ from a Neutral Position
- ☐ to ask a Question

Comments: 11

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Speaker Registration

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Name: Greer Ryan

Organization: Climate Solutions

Address: 1513 SE Morrison Portland, OR

Phone: 812-345-8571

Email:

Meeting Date: 11/1

Topic: Building Energy & climate

Agenda Item You Wish to Speak to:

- ☐ #4 Audience Participation
- ☐ #5 Public Hearing, Topic:
- ☒ #6 Other Business, Topic: Building Energy & climate

You are Speaking…

- ☒ in Support
- ☐ in Opposition
- ☐ from a Neutral Position
- ☐ to ask a Question

Comments:

Scott Stauffer

From: Lisa Batey
Sent: Friday, October 28, 2022 1:52 PM
To: _City Council; Peter Passarelli; Natalie Rogers
Subject: FW: Nat gas

Scott: Please put the email exchange below in the packet for Monday. Thanks!

From: Laura Edmonds <Laura@yourchamber.com>
Sent: Friday, October 28, 2022 11:06 AM
To: Mark Stehn <mark@stehnfuneralhomes.com>; Ann Ober <OberA@milwaukieoregon.gov>; Sandy Stehn <sandy@stehnfuneralhomes.com>; Lisa Batey <BateyL@milwaukieoregon.gov>
Subject: RE: Nat gas

A good reminder that many people have depended on this fuel source over the past few winters.

My family had to come stay with us for about a week due to lost power. Many would have suffered even more had they not had it.

Appreciate your feedback Mark. Fingers crossed that level heads prevail here.

Laura

From: Mark Stehn <mark@stehnfuneralhomes.com>
Sent: Friday, October 28, 2022 11:03 AM
To: Laura Edmonds <Laura@yourchamber.com>; obera@milwaukieoregon.gov; Sandy Stehn <sandy@stehnfuneralhomes.com>; Batey, Lisa <BateyL@milwaukieoregon.gov>
Subject: RE: Nat gas

My mom lives independently and even thought I am close and see her or check on her every day the fact that she have a gas fireplace and gas appliances made a big difference when the power went out last time. We have also installed a generator that is trifuel so propane, nat gas, or good old gasoline at her residence in Milwaukie.

As the price of electricity increases I think we could argue that the city isn't being a good steward of city funds if they have to pay higher prices for power when an alternative is available.

Mark D. Stehn, CFSP

STEHN FAMILY CHAPELS MILWAUKIE Tribute CENTER

2906 SE Harrison Street
Milwaukie, OR 97222
T 503-654-7717 | F 503-652-4085
www.stehnfuneralhomes.com

From: Laura Edmonds <Laura@yourchamber.com>
Sent: Friday, October 28, 2022 10:43 AM
To: Mark Stehn <mark@stehnfuneralhomes.com>; obera@milwaukieoregon.gov; Sandy Stehn <sandy@stehnfuneralhomes.com>; Batey, Lisa <BateyL@milwaukieoregon.gov>
Subject: RE: Nat gas

Mark,

Thank you for your response and I'll include this with other responses that we receive.

As a resident of Milwaukie and a user of natural gas, this bothers me very much. To make such an impactful decision such as this, without putting it to the voters is a breach of trust and I hope that the feedback will prove that our community is not in support of such a drastic action.

Not sure if businesses are being called, but my husband received a call last night and it was apparently a phone poll to ask residence their thoughts on this topic. I was glad to hear that phone calls were finally being made out about this very important topic – but it still needs to go the voters.

Also – in world news Germany is already dismantling 3 of their windmill farms to expand their coal mines due to the energy crisis they are experiencing. We heard from U.S. Congressman Westerman (AZ) this week that China is increasing their coal mine development to the tune of about a mine a week.
If they increase their production at these levels because they are experience major energy shortages – then it's going to pump more toxins into the air.   The conversions to alternative energy sources aren't working for them, demand keeps going up – which is the situation we'll find ourselves in if we insist on going all electric. Wind Farm in Germany Is Being Taken Down for Expansion of Coal Mine (townhall.com)

There must be a better, more reasonable solution to keep a balance of options.

Congressman Westerman was our special guest this week for a conversation on transportation, infrastructure and water.
He serves on the Transportation and Infrastructure Committee.
Subcommittees include the following:
Subcommittee on Railroads, Pipelines, and Hazardous Materials
Subcommittee on Water Resources and Environment
Subcommittee on Highways and Transit

Laura Edmonds

From: Mark Stehn <mark@stehnfuneralhomes.com>
Sent: Friday, October 28, 2022 8:56 AM
To: obera@milwaukieoregon.gov; Sandy Stehn <sandy@stehnfuneralhomes.com>; Batey, Lisa <BateyL@milwaukieoregon.gov>
Cc: Laura Edmonds <Laura@yourchamber.com>
Subject: Nat gas

I was recently made aware of the plan by the city to eliminate natural gas in all city buildings and I am sure eventually to all residence and private businesses in Milwaukie. It interesting that at your last city council meeting The Mayor signed a proclamation regarding national prepared month. Yet at the same time wanting to eliminate an energy source that is both clean and cheap. Redundances are at the core of being prepared.

We recently built a triplex (2019) and are completing a duplex next month and have electric and gas in all units. So the next time there is a winter storm our tenants will have be able to at least have an alternative source of heat when the electricity goes out.

I would like to see this kind of an issue brought to a vote of the citizens of Milwaukie. While I'm not a resident of Milwaukie, we have been serving this community for 45 years our business never closes.

In addition the timing of this when there is an election so close should be taken into consideration. I feel the counsel has tunnel vision around the natural gas issue and may not be taking into consideration other factors. It shows me the lack of leadership and is more than disappointing.

Mark D. Stehn, CFSP

STEHN FAMILY CHAPELS MILWAUKIE Tribute CENTER

2906 SE Harrison Street
Milwaukie, OR 97222
T 503-654-7717 | F 503-652-4085
www.stehnfuneralhomes.com

10/31/22

Mayor and Councilors,

I have lived within the Milwaukie area for nearly 26 years and I have had gas in my residence that entire time. I converted a pellet stove to natural gas and also have gas cooking, bbq, and for water heating. I love natural gas. Last year I was without power for 8 days but was able to cook, bathe and stay warm due to our gas appliances. I would hate to see that choice disappear.

Those people that think NW Natural pipes are unsafe should re-evaluate that idea. NW Natural has one of the tightest pipelines systems in the U.S., having been among the first utilities to replace all of the older cast iron and bare steel pipes. As a result, they have one of the lowest fugitive emissions rates in the country.

How has the City determined what local citizens want? What measures have you taken or what are you planning to take to determine how citizens feel about heating choice? Gas is much more reliable than electricity, costs less and more efficient. With the electric grid still using a lot of natural gas to generate electricity, how much greenhouse gas emissions will be seen? How have you modeled this before taking this drastic step of limiting energy choice?

I firmly believe gas is the cleanest fossil fuel there is and should be an option for any building within our area especially since NW Natural is working everyday to achieve its plan of a carbon neutral pipeline by 2050. If you eliminate this option what would the costs be to replace all the active equipment and how much greenhouse gas emissions will actually be saved by doing this? Is there a more cost-effective way of achieving these emissions such as working with NW Natural a renewable natural gas enhanced offering that citizens of Milwaukie can subscribe to?

Overall I feel there is a great need and desire to keep natural gas in our area. Citizens should have been consulted and provided with accurate information to make that choice. Keep gas as a heating option!

Sincerely

Kathleen Dolezal

503-997-1345

Home Builders Association
of Metropolitan Portland

October 31st, 2022

Mayor Gamba and City Councilors
City of Milwaukie
10722 SE Main St.
Milwaukie, OR 97222

Mayor Gamba and City Councilors:

My name is Preston and I serve as the Director of Government Affairs at the Home Builders Association of Metro Portland. The Home Builders Association ("HBA") represents 1,200 members and tens of thousands of men and women who work in the residential building and remodeling industries throughout the metropolitan Portland area.

The HBA is dedicated to maximizing housing choice for all who reside in our region and supporting industry professionals by shaping an environment in which they can effectively meet the diversified needs of all communities. Our industry has delivered strong economic and community impact in Milwaukie —in the past five years alone, residential builders have generated over $186 million of value and over 900 new housing units in the City of Milwaukie. The downstream impact of this economic engine is multiplied when thinking about the many other industries that rely on and benefit from residential construction.

Our many members have deep experience in bringing energy efficiency and sustainable design to the homes they help build, remodel or upgrade. Given the region's severe housing supply shortage, governments should nurture more cost-effective and diverse energy options that help bring new homes to market while making older homes healthier and more efficient. The combined effect of this approach is greater affordably and more choice for working families and first-time homebuyers. Therefore, we implore policymakers of all stripes to view policies (both new and existing) in light of a vastly undersupplied housing stock—we're roughly 60,000 housing units short in the Portland Region.

With this in mind, I am writing to express our deep concern over the current process unfolding to potentially alter the city's building and energy codes. We believe that, given the strong economic and societal bearing that our industry has on the livability of Milwaukie, the city and council should inform, if not consult, industry partners when considering new building codes related to energy policy and the climate. Additionally, we would encourage the city to release for review the three resolutions that council is considering adopting to foster public input and industry feedback. As a rule, we believe that public policy works best when all stakeholders are represented and engaged.

Additionally, we believe in a balanced energy supply system, recognizing all forms of transitional and renewable energy including renewable hydrogen and natural gas, solar, etc. as part of the solution. Just as best practices dictate having a diverse stock portfolio, a diverse energy portfolio is important to the resiliency and cost effectiveness of the energy system and buildings it serves. The net result is a healthier energy grid, more consumer choice, and greater affordability. Especially as extreme weather events become more common due to climate change, transitioning away from varied and reliable energy sources could overwhelm grids and create potential health and safety challenges for residents. That is why we are concerned when jurisdictions consider unilateral action on energy code policy, especially when that action is as drastic as potentially banning certain forms of energy options in new home construction. Such a move deserves a robust and thoughtful dialogue with public interests.

Lastly, the HBA supports a strong statewide building code system because we know that a uniform building environment supports healthy housing production. We are proud to have one of the nation's most efficient building codes—Oregon ranks #9 in the nation. In the same light, individual building and energy code mandates create confusion among builders working across multiple jurisdictions. Unvetted local mandates often undermine or defeat the purpose of a statewide system and ultimately create a patchwork of disordered compliance requirements, limiting economies and hindering affordability.

To this end we ask the council to table any resolutions regarding energy, climate, or building codes until there is a formalized process for public engagement. We also request that the city publicize a process for gathering community and industry input while ensuring that any policy proposals are data driven and focus on net carbon reduction in both the near and long term. We appreciate that the Milwaukie City Council has robust climate goals and we stand ready to work with all stakeholders in shaping policy that achieves carbon reductions on a meaningful scale.

Thank you for your consideration,

Preston Korst
Director of Public Policy and Government Affairs
Home Builders Association of Metro Portland
15555 Bangy Rd, Lake Oswego, OR 97035
email: prestonk@hbapdx.org
phone: 503-684-1880

Scott Stauffer

From: CenturyLink Customer evans <evans4ski@q.com>
Sent: Monday, October 31, 2022 6:33 PM
To: OCR
Subject: Limiting Energy Choice In Milwaukie

This Message originated outside your organization.

Regarding the topic of limiting energy choice in Milwaukie.
Natural gas is the cleanest burning & most affordable of energy choices available. Pushing the all electric vision for Milwaukie is a recipe for higher cost for businesses and for running a household. As electricity is the highest priced energy available. Building new structures with electricity as the only option may cause business to consider more affordable locations to set up shop. Making Milwaukie a less desireable place for them. The power grid can only handle so much demand as many other cities and states are pushing toward this idea. The talk of going all or mostly solar and wind will not sustain all of the demand. Thus rolling black and brown outs are in our future and sounds uncivilized. Will the future be tearing out existing gas lines and appliances to be replaced with all electric? At what cost? RNG is not the enemy that many groups have labeled it to be. State of the art NG appliances are better than ever, the cleanest burning and most efficient available. Homes and businesses are not the leading cause of air pollution. I ask that you reconsider going in this direction. Lisa Evans

Scott Stauffer

From: Lisa Batey
Sent: Tuesday, November 1, 2022 9:58 AM
To: OCR
Subject: FW: We need all-electric buildings

I am guessing all of Council got this, but not crystal clear. Anyway, forwarding for the record. . .

-----Original Message-----
From: Laura Hanks <laura.hanks7@gmail.com>
Sent: Sunday, October 30, 2022 3:34 PM
To: Lisa Batey <BateyL@milwaukieoregon.gov>
Subject: We need all-electric buildings

Dear Batey,

I'm writing to you today because I believe our community must urgently pass a building electrification policy and phase fossil fuels out of our homes and businesses.

Buildings are responsible for 13% of greenhouse gas emissions in the US, and children in homes with gas stoves face a 42% increased risk of asthma symptoms – that's on par with the risks from secondhand smoke. Burning gas in homes also generates harmful emissions of formaldehyde, methane, nitrogen oxides, and other pollutants.

As your constituent, I'm urging you to do everything in your power to pass a policy that will ensure new buildings in our community are all-electric and help phase gas and other fossil fuels out of existing buildings.

Thank you.

Sincerely,
Laura Hanks, Milwaukie

Scott Stauffer

From: Alma Pinto <alma@communityenergyproject.org>
Sent: Tuesday, November 1, 2022 10:37 AM
To: OCR; Adam Khosroabadi; Lisa Batey; Desi Nicodemus; Kathy Hyzy; Mark Gamba
Cc: Isaiah Kamrar; Samantha Hernandez; Carra Sahler
Subject: Testimony re: Milwaukie's "Building Energy & Climate Resolutions"
Attachments: We sent you safe versions of your files; Testimony re_ Milwaukie's _Building Energy & Climate Resolutions_.pdf

City of Milwaukie Councilors:

My name is Alma Pinto, and I am a resident of Milwaukie in the Island Station neighborhood. I also work as a Climate Justice Associate with Community Energy Project (CEP), a non profit organization that provides weatherization, repairs and energy efficiency upgrades for low income households (as well as educational workshops) in the metro region.

Please see the attached joint testimony from CEP and community advocates in support of the building electrification resolutions introduced at the Milwaukie City Council meeting earlier this fall.

Thank you,
--
Alma Pinto
Climate Justice Associate
Community Energy Project
2705 E. Burnside, Suite 112
Portland, OR 97214
P: 971.544.8706 ext. 7006
Website | Twitter | Facebook
[She, Her, Hers]

November 1, 2022

Dear Mayor Gamba and Milwaukie City Council members,

The undersigned environmental justice, energy justice, and community-based organizations are writing in support of the building electrification resolutions introduced at the Milwaukie City Council meeting earlier this fall. We strongly believe that not only are beneficial electrification policies such as those outlined in the resolutions critical to reducing greenhouse gas emissions and helping the City to meet its climate goals, but that these policies are also central in protecting the health and safety of residents in Milwaukie, and increasing climate resilience and reducing energy burdens by expanding access to high-efficiency heating and cooling with the adoption of heat pumps and heat pump water heaters. This is particularly true when these technologies are paired with energy efficiency solutions. We urge you to pass these resolutions – particularly the resolution to direct staff to work with communities to accelerate an equitable transition to efficient, electric existing buildings – as quickly as possible.

Multiple of our organizations are already working within communities to provide whole-home retrofits to transition vulnerable households to all-electric, fully-weatherized homes. Community Energy Project (CEP), for instance, promotes neighborhood stability by making direct home repairs and energy efficient upgrades for their clients. Their successful programming has helped thousands of households in the region live more comfortably and use less energy. After serving over 500 low-income renters this summer with education and supplies, CEP heard directly from families struggling to stay cool in extreme heat. These folks, many of whom are BIPOC, are asking for comfortable homes, lower bills, and access to clean energy programs and incentives. Passing these resolutions could mean that organizations like ours would be better able to work in Milwaukie alongside the city to ensure that *all* Milwaukie residents benefit from this transition to clean appliances, with a particular focus on low-income households, renters, and BIPOC communities.

The use of methane gas in buildings is one of the top growing sources of greenhouse gas emissions in the state, and as such must be addressed if the City hopes to meet its ambitious climate goals. Studies have shown that pursuing electrification can greatly reduce emissions associated with buildings, with an RMI analysis on electrification in Oregon showing that transitioning a home to all electric would, on average, reduce emissions by 27%. These emissions reductions will only increase as Oregon's electric grid gets closer to 100% renewable generation, as mandated by House Bill 2021.

Beyond just reducing greenhouse gas emissions, transitioning existing buildings to be highly-efficient and all-electric can also help Milwaukie residents reduce their energy bills and burdens. As governments around the world transition off of fossil fuels, the cost of methane gas is fluctuating rapidly. Closer to home, Milwaukie residents can expect to see a 42% increase in their gas bills in just over a year. As gas prices continue to rise, it will become increasingly necessary for cities like Milwaukie to make high efficiency electric appliances more available and affordable to their residents. According to data from the U.S. Census Bureau's American Housing Survey, there are an estimated 35 million low-income U.S. households that could save a combined $15 billion per year on their energy bills if they were using new, efficient electric space and water heaters. Such home upgrades would help provide long-term energy affordability for families and reduce their need for energy assistance. These building electrification resolutions, paired with the recently passed Inflation Reduction Act funding, as well as other federal and state funding, will help accelerate this work in Milwaukie.

Gas is not only hurting our climate and our pocket books, it is also a direct threat to our health and safety. The use of methane gas in buildings is putting residents at increased risk to their health and safety due to the high levels of air pollution that it generates. Transitioning our buildings to highly-efficient electric appliances comes with many community benefits. One of the most significant of these is the dramatic reduction in air pollution generated by gas appliances. A recent study found that children that grow up in homes with gas stoves are 42% more likely to develop asthma symptoms due to associated indoor air pollution. Most recently, scientists in Boston discovered that gas appliances have been leaking methane in buildings - and into the air - at least six times the rate ever previously known or reported. Study after study has shown that indoor and outdoor air pollution, such as that generated by the combustion of fossil fuels like methane in buildings, disproportionately impacts historically marginalized communities, including low-income and Black, Indigenous and People of Color households. Just in the last week, the New York Times highlighted research showing that gas appliances emit benzene, a colorless and odorless known carcinogen, into homes.

To advance values of environmental and economic justice, and to meet its Climate Action Plan goals, the City of Milwaukie must stop the expansion of gas infrastructure and begin a managed transition off of fossil gas altogether. The three proposed resolutions currently before Council are an important and sensible approach to this goal. They balance the need for transition with the reality of gas consumption by setting long term goals for the equitable transition of existing buildings, mandating that new construction be all electric, and working to quickly transition City owned buildings off of polluting gas to lead by example and set a high standard for the region.

As such, we urge you to advance actions that accelerate the equitable transition to all-electric buildings in Milwaukie as quickly as possible.

Thank you for your leadership and your consideration.

Signed,

Alma Pinto, Climate Justice Associate
Community Energy Project

Samantha Hernandez, Climate Justice Organizer
Oregon Physicians for Social Responsibility

Isaiah Kamrar, Program Manager
African American Alliance for Homeownership

Carra Sahler, Staff Attorney
Green Energy Institute

Scott Stauffer

From: Mary Kouba <marykouba@yahoo.com>
Sent: Tuesday, November 1, 2022 12:58 PM
To: OCR
Subject: Ban on natural gas for residential properties.

This Message originated outside your organization.

I very much appreciate your concern for the environment and our impact on climate change. That being said, to ban natural gas for home heating is very short sighted at this time. We, as a nation and a region do not have the capacity to produce all our energy needs from renewable sources at this time.
Switching from natural gas to electric heat would cause our energy costs to soar tremendously. We just replaced our old gas furnace to a high-efficient one. This allowed us to reduce our gas usage by one half cutting our carbon footprint. Is this ban going to be retroactive? If so, who would pay to replace our gas furnace? We are retired and this would be an impossible cost to us. What about brown-outs? Our electric grid may not be able to handle the extra loads. Also, if we can't afford the electric bill, we may have to resort to burning wood in the fireplace to heat the house. Please think of all the consequences and costs this ban would have on the citizens of Milwaukie. Sincerely, Ben and Mary Kouba. 4805 Se Mason Hill Drive
Sent from Yhoo Mail on Android

PACIFIC PROPANE GAS ASSOCIATION

November 1, 2022

Milwaukie City Council
10722 SE Main Street
Milwaukie, Oregon 97222

RE: PPGA Comments on Building Energy Decarbonization Resolutions

Members of the Milwaukie City Council:

On behalf of the Pacific Propane Gas Association (PPGA), which represents propane marketers, suppliers and equipment manufacturers across Oregon, we appreciate the opportunity to provide feedback on propane in general and explain our concerns with the building energy decarbonization resolutions—particularly Resolution 2: Supporting Decarbonization of Existing Buildings and Resolution 3: Decarbonize future homes and buildings.

General Comments

I. Energy Reliability & Resilience

While propane does not likely service many residential customers in Milwaukie as their primary fuel source it may serve as back-up power generation for residential and other commercial buildings. Propane generators provide supplemental power for a building's electrical loads when power from the electric grid is interrupted.

Loss of grid power can occur at any time, whether planned or unplanned. This loss of power to commercial buildings can impact vital systems like smoke, fire, elevators, refrigeration units, heating and cooling equipment, health and safety equipment, communications, and many other applications. For this reason, many commercial buildings such as hospitals, assisted living facilities, offices, etc. utilize propane for backup power generation.

Additionally, some residential buildings may have installed propane generators for back-up power during times of electrical outages.

It is unclear if an assessment has been done regarding back-up power generation and the negative impact an outright ban on propane hook-ups could have on families and businesses using propane during times of emergency.

II. Clean American Energy

Propane can play an important role in Milwaukie and Oregon's clean energy transition and future. Propane burns cleanly, efficiently and has a low-carbon content.[1] Propane's

[1] https://www.eia.gov/environment/emissions/co2_vol_mass.php

environmentally friendly attributes have long been recognized by the federal government and states around the country. It is nontoxic and vaporizes the moment it is released from a pressurized cylinder. As such, and unlike other energy sources, propane presents no threat to soil, surface water or ground water.[2] This helps preserve and protect critical land and water resources, including environmentally sensitive waterways. Propane's combustion produces virtually zero particulate matter.[3]

While the PPGA has concerns regarding the resolutions applicability to natural gas we would note in resolutions 2 and 3 the "Whereas" sections of the resolutions repeatedly reference methane emissions. Propane, however, is a non-methane energy molecule.

III. Renewable Propane

We would highlight our industry is also actively promoting the use of renewable propane as another means to reduce greenhouse gas (GHG) emissions. Renewable propane is a by-product of renewable diesel production, and can be derived from a variety of sustainable sources, such as biomass, animal fats and vegetable oils.[4] And, in addition to retaining all of the same environmentally friendly attributes as traditional propane, it is less carbon intensive.[5] In California, renewable propane being used as a vehicle fuel has a carbon intensity score as low as 20.5, far less than other energy sources.[6]

Beyond transportation, energy molecules produced from sustainable feedstocks, like renewable propane, can also drastically reduce GHG emissions from the buildings and thermal sectors as well.

Additionally, new technologies continue to be developed such as the blending of renewable Dimethyl Ether (rDME) and propane. An 80% rDME and 20% conventional propane blend achieves a near zero carbon intensity score. As an industry, with continued investments we believe propane can get to zero or near zero carbon intensity.

Renewable propane is already in the marketplace in California and Oregon, supporting those states decarbonization efforts. Limiting these technological advancements in Milwaukie, through building codes, limits the city's ability to decarbonize its economy and still remain an attractive place for business and investment.

IV. Zero Net Energy Buildings and Propane.

A "Whereas" in the resolution states a goal of net zero emissions from all buildings by 2035. Buildings can currently be built with propane infrastructure and still achieve Zero Net Energy (ZNE) construction status. By constructing buildings in an extremely energy efficient manner (e.g., minimal air loss, robust insulation), utilizing efficient appliances, and generating

---

[2] https://afdc.energy.gov/fuels/propane_basics.html
[3] https://www.epa.gov/sites/default/files/2020-09/documents/emission_factor_documentation_for_ap42_section_1.5_liquified_petroleum_gas.pdf
[4] https://afdc.energy.gov/fuels/propane_production.html
[5] https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/b0189_summary.pdf
[6] *Id*.

electricity onsite from solar or wind, buildings can still achieve ZNE status while also using propane for energy intensive applications, such as space and water heating. ZNE residential homes are currently being built in California using an "all of the above" energy approach that includes the use of propane. These same technologies can be applied to communities like Milwaukie. ZNE buildings can be achieved without banning propane gas hook-ups as the Resolution No. 3 requires.

V. Eliminates Decarbonation Innovations in other Sectors

Finally, mandating one fuel source limits investments and innovation in decarbonization efforts by current participants in the energy markets. The city's goal of carbon neutrality is noble but the PPGA, respectfully, thinks the goal should be GHG reductions and not electrification. Industries have no incentive to invest in new technologies or decarbonization projects if banned from a marketplace. If the 100% clean electricity assumptions faulter at any point, then critical opportunities to decarbonize other energy sectors may have been lost because those sectors did not feel those investments were worth making in Milwaukie.

Thank you for allowing us to share some information about propane and the impact of these proposals. As it is unclear from our reading of the "whereas" sections of the resolutions that the city has assessed what, if any, impact the ban on propane hook-ups may have on back-up power generation during times of emergency, we would encourage the city to take a pause on these resolutions until a more robust level of community and industry engagement can occur to avoid any unintended consequences.

Sincerely,

Matthew Solak
Executive Director
Pacific Propane Gas Association
(o): 844.585.4940
(c): 269.470.8729
matt@kdafirm.com

Scott Stauffer

From: Carlson, Nina <Nina.Carlson@nwnatural.com>
Sent: Tuesday, November 1, 2022 4:04 PM
To: OCR; Adam Khosroabadi; Mark Gamba; Lisa Batey; Desi Nicodemus; Kathy Hyzy
Subject: Coalition letter regarding resolutions on agenda for Milwaukie City Council November 1, 2022
Attachments: We sent you safe versions of your files; MilwaukieJointLetterNov1_2022.pdf; energies-15-01706-v2 (2).pdf; CSA-Group-Research-Appliance-and-Equipment-Performance-with-Hydrogen-Enriched-Natural-Gases.pdf

Mayor Gamba, Council and Staff,

Please find attached our coalition letter relating to the resolutions around restrictions to energy choice to be presented at tonight's council meeting. We look forward to discussion of pathways to achieve the city's climate goals in a manner that prioritizes equity, safety, reliability and cost as it relates to energy the energy Milwaukie residents depend upon.

Additionally, I would like to submit to the record some clarification on a study that Sierra Club is citing in other jurisdictions around concerns over hydrogen technology and its blending into our modern gas delivery system. I have attached the studies cited below as well, and will have some further follow up for you all in the next week.

> Real life testing on appliances by the GTI Energy[1] and the Canadian Standards Association[2] have shown that NOx is largely unchanged, or in some cases decreases with increasing hydrogen blending.
> [1] Glanville P, Fridlyand A, Sutherland B, Liszka M, Zhao Y, Bingham L, Jorgensen K. Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NOx Emission and Operational Performance. Energies. 2022; 15(5):1706. https://doi.org/10.3390/en15051706
> [1] Suchovsky, C. J., Ericksen, L., Williams, T., & Nikolic, D. (2021, May). Appliance and equipment performance with hydrogen-enriched ... - CSA group. Retrieved July 18, 2022, from https://www.csagroup.org/wp-content/uploads/CSA-Group-Research-Appliance-and-Equipment-Performance-with-Hydrogen-Enriched-Natural-Gases.pdf

Kind regards,

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[1] Glanville P, Fridlyand A, Sutherland B, Liszka M, Zhao Y, Bingham L, Jorgensen K. Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NOx Emission and Operational Performance. Energies. 2022; 15(5):1706. https://doi.org/10.3390/en15051706

[2] Suchovsky, C. J., Ericksen, L., Williams, T., & Nikolic, D. (2021, May). Appliance and equipment performance with hydrogen-enriched ... - CSA group. Retrieved July 18, 2022, from https://www.csagroup.org/wp-content/uploads/CSA-Group-Research-Appliance-and-Equipment-Performance-with-Hydrogen-Enriched-Natural-Gases.pdf

November 1, 2022

Dear Mayor Gamba and Milwaukie City Council,

Thank you for the opportunity to provide comments to you. We have seen that the City is considering a series of resolutions on forced electrification and we are concerned that the resolutions—instead of being measured authorizations and request for City staff to *begin* work—are framed as forgone conclusions that electrifying everything and removing energy choice are the only options to achieve emissions reduction goals. **The City has not yet completed the most basic research necessary to make a recommendation to Council on a policy direction, or, if staff has done that work, none of it has been shared publicly.**

We request the Council not vote on these resolutions at all until the new Milwaukie City Council is sworn into office in January (because policies as impactful as these should be reasoned and reviewed by the new Council in 2023). Further, we request Council not vote on these resolutions until they are reframed as *technology neutral* opportunities to move forward with rigorous analysis, research and outreach work—as currently written, they make the forgone conclusion that electrifying everything is the correct outcome—but that is a false start for good policy making.

(continued to next page)

Once the new Council is sworn in, we request the following:

1. **We request a thorough analysis of the potential impacts of gas bans on our community.** We request to see the carbon emissions modeling, the economic modeling, and the costs to residents and businesses—both capital and operating costs.
    a. There is an inconvenient fact about forced electrification – namely, about half of Oregon's electricity is generated by coal and natural gas.[1] Electric utilities in Oregon use about as much natural gas to generate electricity as is delivered by all the natural gas utilities in the state combined.[2] We expect that the City's analysis will include state level laws and rules for both the electric side and the gas side as well as up to date information from utilities on their Integrated Resource Plans and other plans.
    b. Please include time for the community and utilities to review the staff's modeling work before Council votes.
2. **We request to see a thorough community engagement plan and then also the results of that community outreach and survey work.** We underscore that engagement should include all stakeholders and pay special attention to our most vulnerable residents as well as the small businesses that are the fabric of our community.

Additionally, passage of the Inflation Reduction Act (IRA) incentivizes progress around all forms of renewables, including renewable natural gas and hydrogen. It also includes innovations like carbon capture. This is an all-of-the-above approach to fighting climate change and we encourage the City to review the IRA's funding opportunities—and the IRA's *technology neutral* approach—as part of its analysis.

Finally, while we come from different perspectives, we share a principled approach to thoughtful carbon reduction policies and believe in economic prosperity and housing policies that ensure affordability, reliability and resiliency in the long run for the people we serve and represent. With a group as diversified as our membership—we urge you to meet with us and understand that our requests are backed by years of experience, investment in our community and deeply held belief that working together is the best approach. We can set a course of action that achieves a carbon neutral future without sacrificing the affordability, reliability and energy choice Milwaukie needs.

Sincerely,

Clackamas County Business Alliance
Columbia Pacific Building and Construction Trades Council
International Union of Operating Engineers, Local 701
Ironworkers, Local 29
Home Builders Association of Metropolitan Portland
Lisac's Fireplaces & Stoves
National Electrical Contractors Association – *Oregon Columbia Chapter*
NW Natural
North Clackamas Chamber, Your Chamber
OPEIU, Local 11
Oregon Hearth, Patio & Barbeque Association
Oregon Restaurant & Lodging Association
Portland Metropolitan Association of Realtors
United Association of Plumbers & Steamfitters, Local 290

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[1] https://www.oregon.gov/energy/energy-oregon/Pages/Electricity-Mix-in-Oregon.aspx
[2] https://www.eia.gov/state/print.php?sid=OR

energies

MDPI

Article

Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NO_x Emission and Operational Performance

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Abstract: Several North American utilities are planning to blend hydrogen into gas grids, as a short-term way of addressing the scalable demand for hydrogen and as a long-term decarbonization strategy for 'difficult-to-electrify' end uses. This study documents the impact of 0–30% hydrogen blends by volume on the performance, emissions, and safety of unadjusted equipment in a simulated use environment, focusing on prevalent partially premixed combustion designs. Following a thorough literature review, the authors describe three sets of results: operating standard and "ultra-low NO_x" burners from common heating equipment in "simulators" with hydrogen/methane blends up to 30% by volume, in situ testing of the same heating equipment, and field sampling of a wider range of equipment with 0–10% hydrogen/natural gas blends at a utility-owned training facility. The equipment was successfully operated with up to 30% hydrogen-blended fuels, with limited visual changes to flames, and key trends emerged: (a) a decrease in the input rate from 0 to 30% H_2 up to 11%, often in excess of the Wobbe Index-based predictions; (b) NO_x and CO emissions are flat or decline (air-free or energy-adjusted basis) with increasing hydrogen blending; and (c) a minor decrease (1.2%) or increase (0.9%) in efficiency from 0 to 30% hydrogen blends for standard versus ultra-low NO_x-type water heaters, respectively.

Keywords: hydrogen; natural gas; combustion; partially premixed; water heater; furnace; appliances; NO_x emissions; hythane; hydrogen-blended gas

check for updates

Citation: Glanville, P.; Fridlyand, A.; Sutherland, B.; Liszka, M.; Zhao, Y.; Bingham, L.; Jorgensen, K. Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NO_x Emission and Operational Performance. *Energies* **2022**, *15*, 1706. https://doi.org/10.3390/en15051706

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1. Introduction

The interest in hydrogen in North America on the part of the energy industry is growing rapidly, as a means of supporting climate change mitigation goals with this flexible low-carbon energy carrier. As an energy vector, not unlike electricity, low-carbon hydrogen can be generated in multiple ways, as a means of storing renewable energy ("green" H_2) or decarbonizing fossil natural gas with integrated carbon capture ("blue", "turquoise" H_2). This flexibility has driven a rapid scale up in investment and interest, from numerous utilities initiating programs to inject hydrogen into natural gas networks to Canada's national hydrogen strategy and the U.S. Dept. of Energy's Earthshot program to reach a goal of USD 1/kg H_2 [1,2].

The scale of the decarbonization challenge is not trivial, with a combined U.S./Canadian natural gas network of 5.4 million km serving 85 million homes and businesses, where natural gas combustion in U.S. and Canadian buildings and industry are responsible for a combined 1077 Mt CO_2e/year [3–6]. However, with significant potential as a decarbonized energy vector, blending hydrogen into gas grids serving buildings and industry can serve as both an important short-term way of addressing the scalable demand for hydrogen, driving down costs of generation, storage, and distribution and an important long-term strategy to decarbonize 'difficult-to-electrify' end uses, including those with significant thermal demands, in older buildings, and in cold climates [7–9].

Hydrogen utilization represents one of several important and emerging shifts in the energy industry towards broad decarbonization. While this concept is not new, with North American development of the "green hydrogen" concept going back to the 1970s [10], only recently are multiple large-scale pilots and demonstrations underway, as summarized in Table 1. These efforts build on a prior coordinated shift from one piped gas to another, the transition from manufactured gas to natural gas in the early 20th century. This prior transition is covered well by Tarr in a comprehensive historical account, highlighting that industry-wide, the full transition took 30 to 40 years to accomplish, with the greatest effort concerning the conversion of end-use equipment [11].

Table 1. Selected North American hydrogen/natural gas blending demonstrations.

Location	Details of Demonstration *
Canada—Alberta [12]	ATCO Gas will inject 5% of H_2 by volume starting in late 2022, in a section of its customer network serving approximately 2000 customers.
Canada—Ontario [13]	Enbridge Gas will inject 2% H_2 by volume in a network serving approximately 3600 customers in the Toronto metropolitan area in 2022.
US—California [14]	A joint effort of San Diego Gas & Electric and SoCalGas to perform multiple demonstrations of blending initially from 1 to 5% H_2 by volume up to 20%, in multiple portions of their networks, from 2021 to 2026.
US—Utah [15]	Beginning with 5% H_2 injection at a training facility in the Salt Lake City region, Dominion Energy may expand to customer networks starting in 2022.
US—Oregon [16]	Testing at training facility at 5% H_2 blended, NW Natural may also expand into customer networks into 2022–2023.
US—Hawaii [17]	Not a blending demonstration per se, but Hawaii Gas has long operated a distribution network on Oahu delivering a manufactured gas containing 10–15% H_2 by volume serving approximately 30,000 customers.

* Information current as of 2021.

Concerning these risks of blending hydrogen into the existing natural gas networks in the U.S., several excellent overviews were performed with focus on infrastructure concerns, including a National Renewable Energy Laboratory (NREL) and Gas Technology Institute (GTI) technical review focused on pipeline distribution concerns [18], followed by two comprehensive industry reviews, prepared jointly for the American and Canadian Gas Associations and the Pipeline Research Council International, respectively. Additionally, the heating, ventilation, air-conditioning, and refrigeration (HVAC/R) industry commissioned its own review with a focus on end use equipment [19]. Studies largely point to the European "NaturalHy" Project [20], from 2004 to 2009 that concluded that minor adjustments to equipment in Europe could accommodate fuel blends with up to 20% hydrogen by volume, though given variations in equipment in the U.S. versus Europe, the 2013 study pointed to 5–15% as a range that would "appear to be feasible with very few modifications to existing pipeline systems and end-use appliances" [18]. More recent industry reviews agreed that up to a 20% limit was generally suitable, though the HVAC/R industry's detailed failure analysis approach concluded that only currently (as of 2021) produced equipment should be safe to operate with up to a 20% hydrogen blend, provided that no adjustments are made regarding the reduction in heating capacity, a conclusion largely based on an attempt to certify one piece of North American equipment in Europe [13]. Citing the efficiency benefit of newer products, the study also recommended that existing equipment be replaced and did not specify a hydrogen blend tolerance for equipment currently in operation [19].

Up until recently, most investigations of blended hydrogen's impacts on building equipment, including the highly cited "NaturalHy" project [20], were performed in Europe, and the equipment evaluated differed from that in use in the U.S. and Canada. However, with the growing interest in hydrogen's role as a low-carbon energy carrier, in addition to the continued research in Europe [21], there is a renewed interest in North America, with recent laboratory investigations by UC Irvine [22] and Appliance Engineering [23], in addition to the work described in this paper.

Using a laboratory and field-based approach, the authors investigated the impact of hydrogen-blended natural gas on conventional unadjusted fuel-fired equipment frequently found in North American buildings, specifically the impact on this equipment's performance, emissions, and safety in a simulated use environment. In these buildings, where natural gas (>95% methane) remains the predominant fuel for heating, this study focuses on space and water heating equipment, which consumes 95–97% of natural gas in these applications [24,25], with simplified diagrams of these burners shown in Figure 1. Miscellaneous appliances such as hearth products and cooking equipment, in addition to water heaters and furnaces, were also examined in a field environment, focusing on partially premixed equipment and the resulting NO_x emissions. While residential-sized equipment is evaluated in this study, note that the designs examined are often simply scaled-up in size for commercial building applications, where variants of burners shown in Figure 1 are applied in residential-sized and commercial-sized equipment alike.

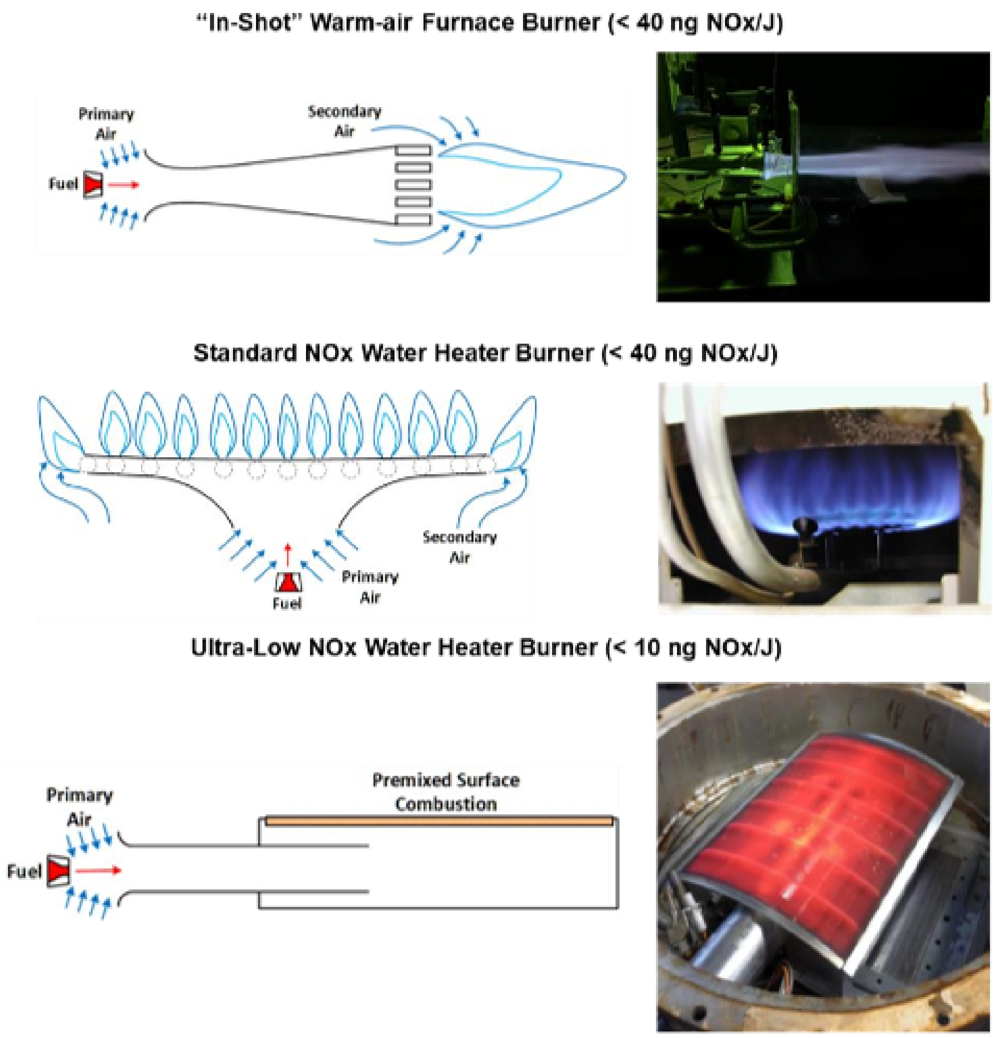


Figure 1. Primary burner types investigated.

With a focus on the U.S. and Canadian context, the goal of this study is to (a) perform a thorough review of the current state of knowledge concerning the performance and emissions impacts of hydrogen-blended natural gas on typical combustion equipment in homes and businesses, (b) expand these datasets with laboratory and field-based sampling of partially premixed type burners and combustion equipment operating with up to 30% hydrogen blends, with a focus on operational performance and NO_x emission impacts, and (c) draw distinctions between common variations, including natural versus induced draft, high versus standard efficiency, and standard versus "ultra-low NO_x" designs.

2. Background

For combustion equipment designed to operate with standard gaseous fuels (natural gas, liquified propane, and manufactured gas), hydrogen presents numerous challenges as a fuel when blended, including its faster flame speed, increased flame temperature, reduced volumetric density, wider flammability range, reduced flame luminosity, and other factors [21–23]. Appendix A provides an overview of the fuel gas quality impacts of blending hydrogen into natural gas.

As apparent in the aforementioned reviews, predicting the tolerance of blended hydrogen in the wide array of combustion-based end-use equipment is challenging, in large part due to the limited datasets available. For earlier studies, hydrogen tolerance of existing end use equipment was based largely on a small number of older European studies [18], while more recent assessments analyzed an expanded dataset for residential and commercial-sized equipment; however, they remain limited (<30 pieces of equipment) [19]. This presents a challenge to utilities when considering the injection of hydrogen into existing natural gas networks, as the short-term and long-term impacts on the wide diversity of combustion equipment downstream remain uncertain.

$$\text{Combustion Air Requirement} = \frac{(\text{Air to Fuel Ratio})_{\text{stoichiometric}}}{\sqrt{\text{SG}_{\text{fuel}}}}$$

2.1. Equipment Testing Data

Despite noted challenges with predicting equipment impacts on gas quality alone, for fuel-fired heating and cooking equipment in North America considered in this study, general trends do apply to the major combustion system types with hydrogen blending. As with this study, the following applies to "moderate" levels of hydrogen blending into natural gas at or less than 30% by volume, though equipment-specific impacts can vary:

1. All unadjusted equipment will see reductions in heating output with increased hydrogen added. For steady-state (i.e., on/off) equipment, manual adjustments are possible, but may not be necessary. For equipment meeting a thermal demand, equipment may be manually or automatically adjusted to compensate, and unadjusted equipment will compensate with longer runtimes.
2. Partially premixed combustion systems will likely see an increase in primary aeration, resulting in the potential for concerns with flame stability and temperature, leading to flashback and increased thermal NO_x emissions, respectively. However, the available test data show that for moderate ranges of blending (<30%), flame stability is generally not an issue and NO_x emissions are stable or decline [22,23], as will also be shown later in this paper. As a class, these are the most common combustion system types in North America, due to low cost and high reliability, including most furnaces, water heaters, boilers, cooking equipment, and hearth products.
3. Premixed combustion system impacts will vary by the control of fuel/air mixing, as the impact of hydrogen addition varies accordingly. For common pneumatically controlled fuel/air mixing, the air flow remains approximately constant as hydrogen is added, and thus combustion shifts to being leaner (λ increases), which can counteract the impact hydrogen has on flame temperature, speed, and stability. For electronically (or "digitally") controlled fuel/air mixing, often a constant-λ approach is employed, the equipment automatically compensates for the change in fuel properties with added hydrogen, requiring additional compensation to avoid flame stability issues. Premixed systems are commonly used in high-efficiency equipment where the precise control

and modulation can be valued, and pressurization of the combustion chamber(s) is needed to overcome heat exchanger pressure losses. Examples of common equipment classes that utilize premixed combustion include tankless water heaters, combi boilers, fuel-fired heat pumps, micro-combined heat and power, and equipment required to meet ultra-low emission requirements (<14 ng NO_x/J).

4. Non-premixed (diffusion) combustion systems have a greater tendency towards flame lift, though these have been observed to be minor in practice at moderate ranges of blending (up to 30%). While there are many examples of non-premixed combustion in daily life, from candle flames to wood fires, these are not common with gaseous fuels due to the poor combustion control. Examples are limited to decorative flames (e.g., gas lights), log lighters, and individual pilot lights.

While published datasets of equipment testing are scarce, an excellent review provided additional insights, largely based on the testing of European-style premixed combustion systems (e.g., hot water domestic boilers) [21]. Broadly, with increasing hydrogen blending, efficiency impacts are generally small (<2%) or within measurement error. Flame ionization sensors showed measurable declines in the control signal requiring further investigation; however, this impact did not warrant overall safety concerns. Similarly, an impact on ignition was not observed for hydrogen addition. The impact on flame temperature was mixed, though generally studies showing the region near the flame did increase in temperature but combustion chamber temperatures declined due to the increase in excess air levels. Regarding emissions, generally CO and NO_x emissions are shown to decrease or remain the same with added hydrogen. Regarding flame stability issues such as flashback, this is observed in some studies with higher hydrogen blend ratios, at or above 20% for fuel-rich combustion and at or above 40–50% for standard combustion. These stability issues are not well characterized in the literature, some appearing to be random, and cannot be explained by hydrogen addition alone [21].

For the North American context, these findings do not always translate to the prevalent partially premixed combustion-type water heaters, furnaces, and cooking equipment. Two recent datasets provide insights on North American appliances, though studies differed in the equipment tested, the operating conditions, the test method and instrumentation employed, and the analytical approaches. Additionally, one study included the operation of all equipment at 5 and 15% hydrogen blended with methane, while the second study varied the blending ratio into natural gas by appliance, depending on observations and experimental limitations. With these disclaimers noted, the following consistent results between datasets concerning furnaces, boilers, and water heaters that primarily use partially premixed combustion system designs can be observed [22,23,26–28]:

1. Equipment de-rating was a consistent result, wherein hydrogen blending decreases the input rate of equipment that the shift in Wobbe Index generally underpredicts, where more than a 3.5% de-rate is observed at 15% H_2 in most instances.
2. The impact on CO and NO_x emissions from unadjusted equipment with hydrogen blending is inherently complex and it is a common misconception, particularly for NO_x, that hydrogen blending rates are proportional to rates of emissions. In principle, unadjusted partially premixed equipment will experience competing factors towards CO and NO_x emission increases owing to the shifts in the gas quality and availability and distribution of combustion air. In most cases, for the furnaces, boilers, and water heaters, the 15% H_2 case had CO emissions within $\pm$10 ppm air-free (AF) from baseline and NO_x emissions $\pm$5 ppm AF from baseline, though some boilers saw significant decreases from the baseline of both. In all cases, the overall fuel/air ratio shifted lower as predicted, as observed with stack O_2 and CO_2 measured.

The current study seeks to both (a) expand the dataset for a broader range of equipment types, with variation within categories (high vs. low efficiency) and (b) quantify these impacts through steady and dynamic experiments, simulated use and extreme scenarios, from 0 to 30% hydrogen blends.

2.2. Partially Premixed Burner Typologies

Figure 2 schematically illustrates the three types of burners tested in the laboratory as part of this study. These burners belong to a broader category of "self-aspirating" or "inspirating" burners, whereby some or all the air required for combustion is entrained into the burner body by an expanding fuel gas jet through momentum transfer. Most commonly, these types of burners are implemented as "partially premixed" burners, where less than 100% of the air required for complete combustion is injected as "primary air". "Secondary air" is then required to complete combustion outside the burner body. Flames from these types of burners exhibit a distinct "double flame" structure, where a bright inner-cone of a rich-premixed flame is visible, surrounded by a duller outer cone diffusion flame. Gas manifold pressures of 3.5–12 mbar are commonly used with these types of burners to inject gas into the body of the burner. Both the "pancake" water heater and the "in-shot" burners illustrated in Figure 2a,b are examples of partial premix systems. Other types of appliances where these styles of burners are common include gas ranges, clothes dryers, decorative fireplaces, space heaters, older boilers, grills, commercial ovens and fryers, among others.

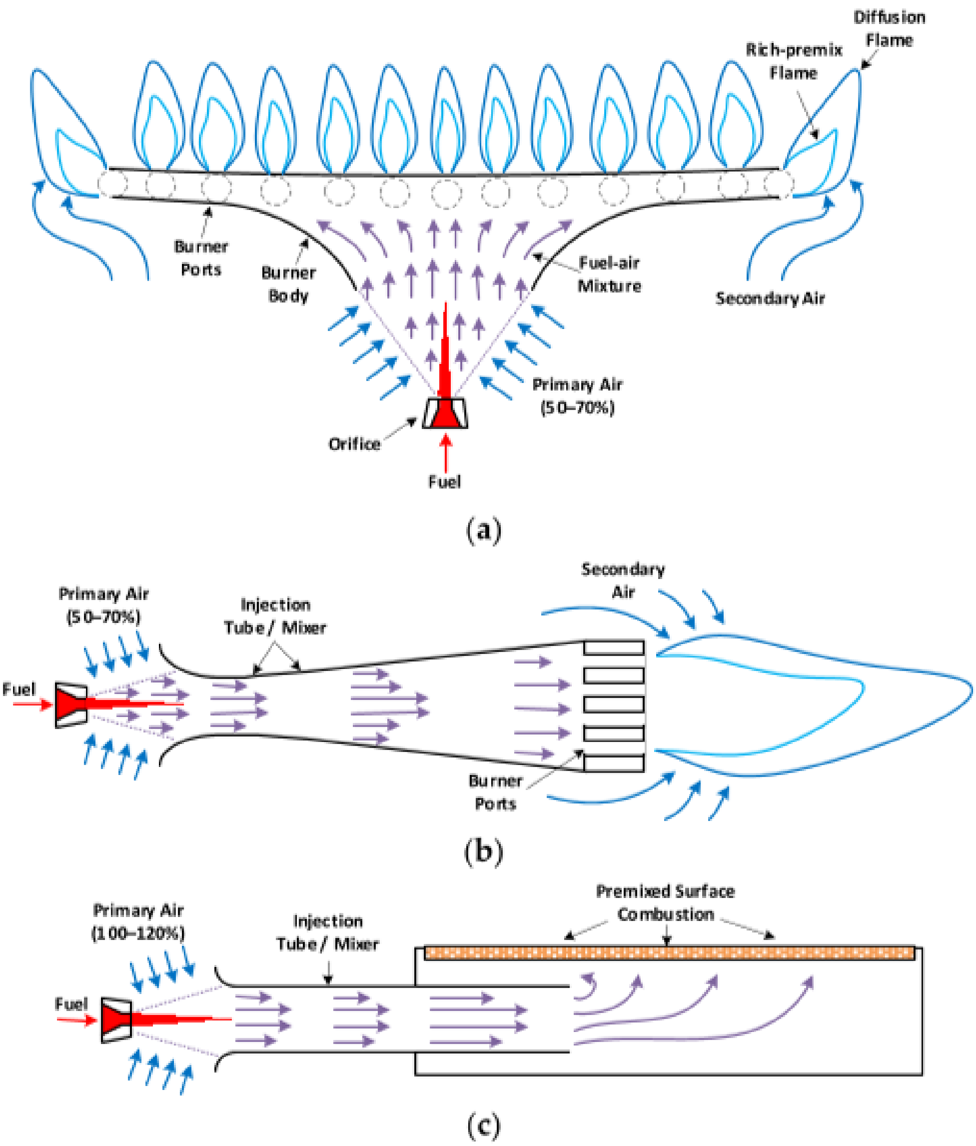


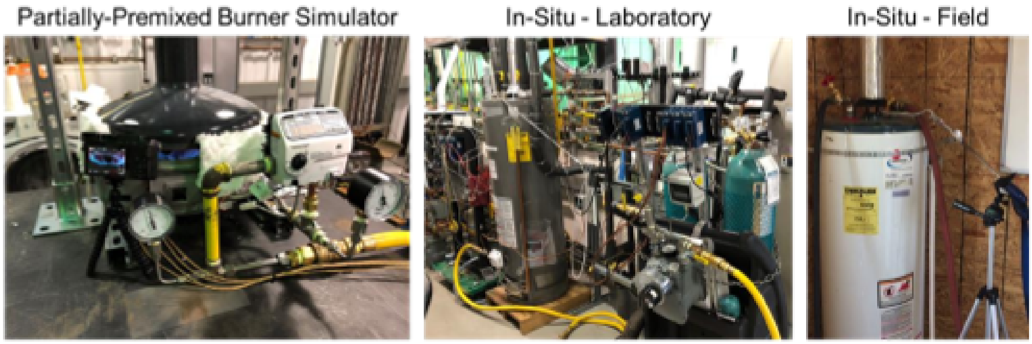
Figure 2. Schematic illustrations of typical North American atmospheric burners, including: (**a**) a "pancake" partially premixed burner from a storage water heater; (**b**) an "in-shot" partially premixed burner from a modern residential furnace; (**c**) an premixed ultra-low NO_x burner from a storage water heater.

The prevalence of partially premixed burners in North America can be in the large part attributed to their low cost (often stamped steel or cast iron), simplicity (can be unpowered), as well as stable and efficient operation [29]. The amount of primary air injected is typically 50–70% [30], leading to a rich-premix flame with a laminar speed of less than 50% of the maximum [31]. The reduced flame speed makes the burner more resistant to flashback, while consuming most of the fuel. To complete combustion, secondary air is entrained into a diffusion flame either through a naturally induced draft (pancake) or a forced draft (in-shot). In the latter case, induced draft is required to allow the burner to operate in a horizontal orientation without allowing the flame to impinge on the heat exchanger (common in North American furnaces).

Additionally illustrated in Figure 2c is a unique fully premixed self-aspirating burner. In North America, these types of burners are used for ultra-low NO_x water heaters, as required by local laws in both California and Utah. To achieve ultra-low NO_x levels of emissions, these burners rely on a radiant screen (metal wire, perforated plate, or ceramic) to absorb some of the heat of combustion and radiate it back out along the surface. This phenomenon has the effect of reducing the gaseous flame temperature and stabilizes the flame near the surface with an overall smaller reaction volume [29,30]. This in turn reduces the formation of NO_x [32]. What makes the burner in Figure 2c unique is how it achieves fully premixed operation. Instead of using a blower and a pressurized combustion system, the burner in Figure 2c relies on self-aspiration to inject nearly 100% of the air required for complete combustion (by means of a large port area [30]). To get up to 115–120% of stoichiometric air for complete combustion, this burner relies on a natural draft established inside the water heater flue to draw additional air through the burner inlet, which is positioned outside the combustion chamber (i.e., the burner outlet is at a negative pressure relative to the burner inlet). Regardless of whether they are partially or fully premixed, the types of burners depicted Figure 2 have operating characteristics (firing rate, fraction primary air, and port loading) that are sensitive to the geometry, operating conditions, as well as the gas properties. While a self-aspirating burner can be designed to operate using any type of gaseous fuel [30], if the fuel properties suddenly change, the same burner may become susceptible to flashback, flame lift, or other instabilities.

3. Methods

In this study, a comprehensive approach was used to characterize the impacts of hydrogen blended with natural gas on common North American fuel-fired equipment. First, the authors built and operated two partially premixed combustion system "simulators" to represent a storage-type water heater and warm-air furnace combustion chambers. These simulators were used to evaluate common burners and their controls, while permitting imaging and direct observation of qualitative impacts on flame appearance, stability, and other factors. Second, the authors identified and acquired five appliances, including conventional (standard NO_x) and ultra-low-NO_x versions, and designed flexible test stands to evaluate each appliance with natural gas mixtures with increasing hydrogen content, with a focus on mass-market products. For these laboratory tests, the burners and equipment were operated with pipeline natural gas and mixtures of methane/hydrogen ranging from 0 to 30% hydrogen by volume. Finally, the authors travelled to a North American utility-owned training facility, consisting of a collection of small buildings, to perform field sampling of emissions from fifteen (15) appliances that included water heaters, furnaces, ranges, ovens, dryers, and a fireplace. In the field, emission measurements were taken for all appliances operated with 100% natural gas and a blend of approximately 5% hydrogen and 95% natural gas, with one water heater also tested at a 10% hydrogen blend. While many aspects of equipment operation were examined, the primary focus concerned the measured emissions of NO_x. Figure 3 below highlights this progression of testing for water heaters, from the simulator, to in situ testing in the laboratory, and then the field.



(a) (b) (c)

Figure 3. Example of approach with: (**a**) water heater simulator testing; (**b**) laboratory testing; (**c**) field testing.

3.1. Laboratory Testing

Two sets of tests were performed with a focus on the two primary categories of equipment in North American homes, the fuel-fired storage-type water heater and the warm-air furnace, one or both used in more than half of North American homes [24]. Custom fueling rigs were built for open air and in situ testing, which fed the experimental equipment with natural gas, 100% methane, and hydrogen/methane mixtures from 5 to 30% hydrogen with increments of 5%. An upper limit of 30% was selected a priori due to the anticipated suitability with most equipment, based on the literature review and discussions with manufacturers; however, this is not suggestive as an upper limit of hydrogen tolerance for any equipment tested. Fuel mixtures were supplied from cylinders with a simplified process, and the instrumentation diagram of the fueling rig is shown in Figure 4, while the instrumentation, analyzers, and other equipment used are listed in Table 2 below. The semi-portable fueling rig comprised a cylinder cart and an instrumentation cart which allowed the rig to be easily moved around to various test locations. No filters were used with either the gas from the cylinder or from the building supply. The gas supply from the high-pressure cylinders was allowed to expand naturally, resulting in a ~6 °C degree drop in some instances. An improvement for the future will be to better control the gas supply temperature, which varied in the present study by 5–6 °C.

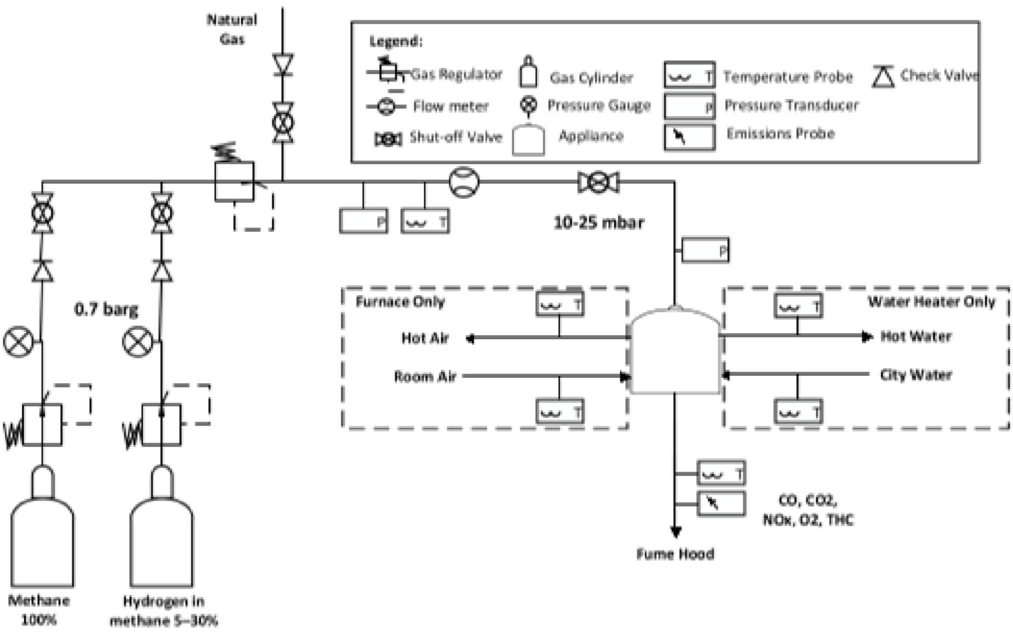


Figure 4. Simplified Process and Instrumentation Diagram (P&ID) of experimental fueling rig.

Table 2. Summary of instrumentation used in simulator and in situ laboratory testing.

Measurement	Instrument/Analyzer Used	Calibration Range/ Instrument Accuracy
Total Hydrocarbons (THC)	Rosemount Analytical 400A	800 ppm
NO_x (NO and NO_2)	Ecophysics CLD 700EL	80 ppm NO
O_2	Rosemount Analytical X-Stream	8% O_2
CO/CO_2	Rosemount Analytical X-Stream	400 ppm CO, 18% CO_2
Fuel Pressure	Dwyer ISDP-008	±31.1 Pa
Fuel Flow	Elster DTM-200A Gas Meter	±1% of reading (prec.: 17.7 pulses per L)
Gas/Air Temperatures	T-type/K-type thermocouples	±0.75% of reading
Atmospheric Pressure	Traceable Excursion-Trac Barometer	±406 Pa
Water pressure	Ashcroft G2 (0–6.9 bar)	±1.0% full scale
Water Temperatures	Omega P-M-1/10-1/8-6-0-P-3 RTDs	1/10 DIN (less than ± 0.08 °C at 60 °C, less than ± 0.04 °F at 10 °C)
Supply Water Flow	Dwyer MFS2-3	±1% of reading

Regarding the natural gas supplied during testing, house gas analysis of the natural gas supply to the lab showed it to contain 93.5% methane by volume and have a higher heating value of 38.8 MJ/m^3 (1042.4 Btu/scf). For the water heater burners, the ignition process was controlled and the fuel supplied, using an unmodified storage water heater gas valve in simulator testing with a 10.0 mbar manifold pressure. Supply pressure was kept at or slightly above 17.0 mbar. For the furnace simulator, the "high" and "low" firing rates were controlled by manifold pressures of 8.7 and 3.7 mbar, respectively. All in situ testing was initially calibrated to manufacturer requirements with pipeline natural gas conditions and then held constant for methane and hydrogen/methane blends. All tests were performed at an altitude of 196 m above sea level.

3.1.1. Simulator Testing Details

The primary goal with testing using "simulators" of water heaters and furnaces was to gather quantitative and qualitative data on the short-term operation of the appliance burners alone, while providing physical and visual access not afforded by testing equipment (burners in situ). Representing most installed gas-fired water heaters, both the standard and ultra-low NO_x type, and warm-air furnaces in North America, four burners were evaluated using simulators. Burners were removed from appliances, installed in simulated operating environments, and operated with standard controls and boundary conditions (e.g., fuel pressure). Exhaust properties were measured, including temperature and composition, in addition to fuel inlet conditions (temperature, pressure, and flow) and burner surface temperatures at multiple locations. Visually, photography and video were used to capture the dynamic impacts of hydrogen addition on flame ignition, start-up, and steady operation, provided that successful start-up was demonstrated, using a digital single-lens reflex (DSLR) camera.

Test durations were up to 10 min, until loss of flame, or until flame instability and/or an unsafe combustion condition was observed (e.g., >400 ppm CO air-free). If the measured surface temperatures were observed to climb for the duration of the 10 min test period, then the test period was extended such that no appreciable trend of increasing burner surface temperatures was observed for at least 5 min. The purpose of these tests was to observe and record the ignition process, and to determine whether stable combustion was achieved and could be maintained afterwards.

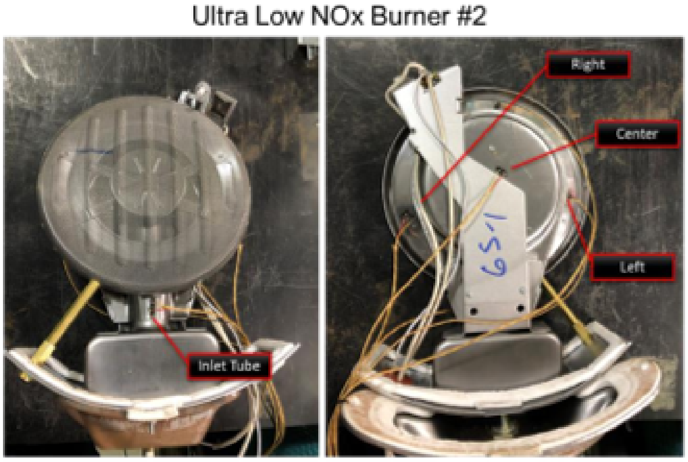
Each burner was first tested with natural gas, then 100% methane, followed by hydrogen–methane mixtures from 5 to 30% hydrogen by volume in increments of 5%. Natural gas served as the baseline for the burner operation and adjustments, with properties such as gas pressures, orifice sizes, and simulator controls held constant for subsequent fuels. Both "cold" and "hot" starts were performed, where the latter represented cycling, operating the burner after a loss of flame/re-light operation. As the blended hydrogen fraction increased, the original objective was to terminate the test at a hydrogen level where instabilities or inconsistent operation were observed. However, in all cases, tests were performed up to the a priori limit of 30%. The following issues of concern were monitored with increasing hydrogen blending:

1. Uneven flame distribution and hot spots: particularly for ultra-low NO_x burners. These burners have a larger burner port/flame holder surface area to decrease the flame temperature for NOx control.
2. Overheating of burner material: this could occur in any of the burners, but most readily in the "pancake" and "in-shot" burners because of the higher port loading compared to the other burners.
3. Flashback and/or formation of a diffusion flame at the burner orifice: The higher flame speed and wider flammability range of hydrogen makes it possible for a flame to occur where it would otherwise not be possible with methane or natural gas. The simple flow-through design of the "in-shot" furnace burners makes them particularly susceptible to this.

The water heater simulator (Figure 3) approximated the operating environment of a water heater while providing ease of visual access to the burners. The simulator was based on a combustion chamber and flue segments from an unassembled water heater. The burners were tested in the bottom portion of a water heater combustion chamber, and a storage water heater flue piece was suspended above the combustion chamber with a ~2.5 cm gap between the top of the combustion chamber and the flue section. The gap between the bottom portion of the combustion chamber and the fuel input assembly was partially covered with ceramic fiber insulation to minimize flue gas dilution and to establish a draft for the burners. A small opening was left to serve as an observation port and to allow for ease of recording unobstructed videos of the ignition and combustion process. In addition to measuring fuel properties (temperature, pressure) and exhaust gas analysis, burner surface temperatures were measured during simulator testing. The diagrams in Figure 5 show the location and naming of welded surface thermocouples for the ultra-low NO_x (ULN) burner designs #1 and #2. Given the similarities in geometry, the circular Standard NO_x "pancake burner" (Figure 1) had similar locations and identical naming to those thermocouples shown for ULN burner #2.

(**a**)

Figure 5. *Cont.*



(**b**)

Figure 5. Ultra-low NO_x water heater burners with positions of thermocouples: (**a**) #1 and; (**b**) #2.

The induced draft warm-air furnace simulator was constructed to approximate the operating environment and for visual access to the "in-shot" burner, with an example pictured in Figure 6. As the typical furnace flame is a "loose" flame, flame stability and structure were a key component of the testing, and unique methodologies of qualifying these were provided using the simulator. The simulator comprised a solid steel metal U-pip with a burner and borosilicate glass tube at the inlet, a water-cooled heat exchange loop, and an induced-draft blower at the outlet. The system was completely sealed outside of the inlet and outlet portions with insulation provided on the body of the loop, as shown in Figure 6, covered with fiberglass insulation for safety.

(**a**) (**b**)

Figure 6. Photos of furnace simulator: (**a**) flow path; (**b**) placement of camera.

The "in-shot" burner used was a typical design found in residential forced-air furnaces, made of stamped sheet metal and carry-over flamelets on either side of the main burner outlet for ignition propagation, with an orifice size 2.08 mm providing the fuel. The burner was situated 3.2 cm from an inlet plate that has an inlet hole 3.2 cm in diameter with the burner being concentric with the inlet hole—the placement and dimensions were taken from a non-condensing residential furnace on site later used for in situ testing.

During tests, the visible flame resided within the borosilicate glass tube, immediately after the inlet plate, and the glass tube was 46 cm long, 9 cm in diameter, and 0.3 cm thick. The upstream end of the tube was compressed into glass fiber insulation that covers the inlet plate, and the downstream end of the tube was inserted 5 cm into the metal framing of the simulator body, with insulation compressed radially at the interface of the glass and body. The "U"-shaped steel flow path downstream of the glass and viewing tube and temperature measurement point contained water-cooled copper tubing loops. An inducer fan was installed at the outlet of the U-tube, modulated by a custom-built controller providing a pulse width modulation signal with digital tachometer output. Measurements included flue gas composition and the following temperatures: (1) that of a thermocouple welded to the burner body itself, approximately 1 cm from the burner face, (2) that of a thermocouple placed 20 cm downstream of the glass tube-to-metal housing transition, with the bead in the centerline, recessed 0.6 cm into the body of a shielding tube to limit radiant heat from the flame, and (3) that of a thermocouple placed 10 cm upstream of inducer blower in order to prevent damage to the impeller. Emission measurements were performed 15 cm upstream of the inducer, immediately after the copper cooling coils.

Two firing rates were used based on a common two-stage reference residential furnace, with a 5.9 kW "High" fire and a 4.1 kW "Low" fire, set with natural gas as a reference fuel based on manifold pressures noted previously. The inducer blower speed was adjusted such that that the horizontal flame did not impinge on the glass observation tube and to minimize exhaust temperatures to protect the inducer. The nominal stack O_2 concentration was 14% by volume (dry), set with natural gas. The inducer speed was then kept constant for the remaining tests. For ignition control, a standard control module was used with a self-grounding spark ignitor and separate flame sense rod. The spark ignitor was placed 1 cm downstream from the burner face and the flame sense rod placed 1.3 cm from the burner face, both placed in the center of the primary burner face. The fuel flow was controlled via an unmodified gas valve which in turn was controlled via a signal from the ignition module, operated with a manual switch.

3.1.2. In Situ Testing Details

In situ equipment testing was performed with three water heaters and two furnaces. The appliances were operated with simulated loads, with imposed draws on the water heater and simulated thermostat calls for the furnace. Each appliance was first adjusted using natural gas (supply pressure and flue installation) and then tested with hydrogen blended with methane in the 0–30% range by volume, in 5% increments. The appliances were installed and operated in a manner consistent with manufacturer requirements (aside from fuel mixture). The three water heaters selected used the three open air burners as shipped, the standard NO_x "pancake" burner, ULN burner #1, and ULN burner #2, respectively. As is common in industry, the furnaces both used variations on the "in-shot" burner design. While four manufacturers were represented amongst the five products selected, where the "pancake" burner and ULN #1 burner-type water heaters were from the same OEM, an important note is that *results should not be viewed as manufacturer-specific, but reflecting the authors' operation of these appliances as per this test plan*. Testing and analysis of the results was not performed in consultation with equipment manufacturers and, due to the nature of laboratory testing, may not reflect the impacts observed in a field environment.

Table 3 summarizes the equipment tested, noting that the efficiency of water heaters and furnaces are shown in terms of the uniform energy factor (UEF) or annual fuel utilization efficiency (AFUE), common in North America [33,34]. For the water heaters, measurements of inlet and outlet water temperatures and flow rates facilitated an energy balance. The furnace testing used an air handler unit (AHU) for ducting, which was instrumented for air-side temperature and pressure measurements, allowing for an air-side energy balance to be completed. Fuel flow was measured using the previously described fueling rig.

Each steady-state operating point was deemed complete based on observation of the burner surface and exhaust temperatures. For water heater tests, the test was concluded once the aquastat setpoint temperature was reached and the ignition controller turned off the burner. The ignition process used existing hardware, either a pilot light or electronic ignition, and for each fuel the tests were conducted from a "cold" start with the furnaces at room temperature (~20 °C) and with water heaters after they had been flushed with cold water such that the inlet and outlet temperature from the water heater were within 2.8 °C of the incoming water temperature at the time of testing, and a re-ignition attempt immediately after the previous test to represent a "hot" start. Throughout all test points, emission measurements (CO, CO_2, NO_x, O_2, THC on a dry basis) and stack temperature were measured to determine the appliance performance and combustion efficiency.

Table 3. Equipment used in in situ laboratory testing.

Equipment Name	Burner Type	Description and Key Features
Standard Water Heater	"Pancake" Burner	Standard NO_x, 0.62 UEF, 189 L, 11.7 kW input
ULN Water Heater #1	ULN Burner #1	Ultra-low NO_x, 0.64 UEF, 151 L, 11.7 kW r input
ULN Water Heater #2	ULN Burner #2	Ultra-low NO_x, 0.58 UEF, 151 L, 11.1 kW input
Non-Condensing Furnace	"In-Shot" Burners	Standard NO_x, 80% AFUE, High Fire = 23.4 kW, Low Fire = 18.8 kW
Condensing Furnace	"In-Shot" Burners	Standard NO_x, 95% AFUE, Input (Single Stage) = 16.4 kW

Specific to the water heaters, a cycling test and the first draw with full recovery was completed for the standard water heater and ULN water heater #1, with only methane and the fuel blend containing 30% hydrogen to measure the recovery efficiency as defined by the U.S. standard [33]. Each water heater also underwent a "slug test" where the water heater was operated continuously by imposing a constant draw with the fuel mixture containing 5% hydrogen initially. The fuel supply then was switched to the mixture containing 30% hydrogen. The water heater was further operated for at least 5 min, and then the fuel was switched again to the mixture containing 5% hydrogen. This test was conducted to see if rapid changes in fuel composition would negatively impact the stability of the burner.

3.2. Field Equipment Sampling

To supplement the laboratory tests, field sampling was performed at a natural gas utility training facility, wherein a wide range of common fuel-fired equipment is operated in a simulated residential environment, with 5–7 groups of equipment installed in 14 mock homes. Sampling occurred over the span of a week, where hydrogen blending was performed on-site with pipeline natural gas into the network serving this facility, which is located in a high-altitude region (>1 km above sea level).

The appliances were tested as installed using unmodified controls. Emission measurements were taken at locations that were most convenient to minimize the alteration of appliance operation. In some instances, the exhaust flue was partially removed from the appliance to provide a location for measuring emissions, but no other modifications were made that could have provided better access to measurement locations. Table 4 highlights the residential equipment sampled, which excludes dryers due to challenges with drawing an accurate sample from a highly diluted exhaust stream without significant modification to the appliance. Relevant to the equipment emission sampling periods, the actual hydrogen blending and fuel heating values are shown in Table 5.

For all stack measurements, a Bacharach model PCA400 was used for the emission tests. The emissions analyzer was calibrated prior to travel by the manufacturer, with a National Institute of Standards and Technology (NIST) traceable certificate of calibration available upon request. The measurement ranges and accuracies for each of the reported measurements and derived values are listed below in Table 6. Except for dryers, most appliances were able to be run in a continuous fashion to allow enough time for the sensors to become fully saturated and meet response time requirements.

Table 4. Equipment used in field sampling.

Location	Equipment Name	Burner Type	Description and Key Features
A	Water Heater #1	"Pancake" Burner	Standard NO_x, 0.59 UEF, 151 L, 11.7 kW input
B	Water Heater #2	"Pancake" Burner	Standard NO_x, 0.59 UEF, 151 L, 11.7 kW input
D	Water Heater #3	ULN Burner #2	Ultra-low NO_x, 0.62 UEF, 144 L, 10.6 kW input
E	Water Heater #4	"Pancake" Burner	Standard NO_x, 0.59 UEF, 151 L, 10.6 kW input
D	Furnace #1	"In-shot" Burners	Standard NO_x, 80% AFUE, Input (Single Stage) = 25.8 kW
E	Furnace #2	"In-shot" Burners	Standard NO_x, 80% AFUE, High Fire = 14.7 kW, Low Fire = 10.3 kW
B	Wall Furnace #1	"In-shot" Burners	66% AFUE, Input = 14.7 kW
G	Wall Furnace #2	"Ribbon" Burners	Input = 23.4 kW
C	Fireplace #1	Perforated Burner	Input = 8.8 kW
A	Range/Oven #1	Standard Range Burner	Max. Input = 15.5 kW
E	Range/Oven #2	Standard Range Burner	Max. Input = 19.9 kW
F	Range/Oven #3	Standard Range Burner	Max. Input = 19.2 kW

Table 5. Gas quality details during field sampling.

Sampling Day	Hydrogen Blend (Actual %)	Heating Value (Average, MJ/m^3)
1 *	4.49	37.63
2	5.18 ± 0.39	37.56 ± 0.15
3	0.00	38.90 ± 0.26
4 **	10.02 ± 0.43	35.95 ± 0.11

* Applies to Location D only. ** Applies to Water Heater #3 only.

Table 6. Field emission sampling analyzer details.

Qty.	Range	Resolution	Accuracy	Response Time
O_2	0 to 20.9%	0.1%	±0.3 %	T90 < 20 s
CO	0 to 10,000 ppm	1 ppm	±10 ppm (0 to 200) ±5% reading (201 to 2000)	T90 < 40 s
NO	0 to 3000 ppm	1 ppm	±3 ppm (0 to 50) ±5% reading (51 to 2000)	T90 < 30 s
NO_2	0 to 500 ppm	1 ppm	±3 ppm (0 to 50) ±5% reading (51 to 500)	T90 < 40 s
T_{flue}	−20 °C to 1200 °C	0.05 °C	±0.5 °C	T90 < 70 s

Most of the tests used sample periods of 10 min with data collected at 5 s intervals. The emissions analyzer was purged outdoors in fresh air before each 10 min sample run. The emissions analyzer also underwent CO auto-zeroing during each startup. As cooling would occur in the corrugated stainless-steel tubing (CSST) where used, a sheathed Type K thermocouple was added to the ambient temperature port of the side of the Bacharach PCA400 to give an indication of the flue gas temperature in addition to the sample gas temperature. This helped to provide a rough determination of appliance operation. The sample lines water trap was adjusted to the vertical position to ensure proper sampling.

The filter in the water trap assembly was checked daily to ensure no water had condensed in the probe/CSST and bypassed the water trap to soak the filter. Examples of appliance exhaust sampling methods are shown in Figure 7.

(a) (b)

Figure 7. Field-testing exhaust sampling examples for: (**a**) water heaters; (**b**) furnaces.

4. Results

4.1. Laboratory Testing

With the partially premixed combustion simulators built and commissioned, recreating storage-type water heaters and warm-air furnaces, four common burners in use in North America were installed and tested with natural gas and 0–30% hydrogen blended with methane, using 5% increments. ULN burner #1 was operated "as-shipped" and with a common orifice to the "pancake" burner to match nameplate input rates, the latter noted as "orifice". For in situ testing, three water heaters were installed and operated with natural gas and hydrogen/methane blends ranging from 0 to 30%, with cold starts (cold tank), hot starts, "slug tests" varying fuel mixtures dynamically, and a recovery efficiency test for two of the three water heaters. Of the three water heaters used, each contained one of the burner types tested in simulator testing. Two furnaces were installed and tested with the same range of fuel mixtures, a non-condensing dual-stage furnace and a condensing single-stage furnace. All in situ water heaters and furnaces were tested "as-shipped", without adjustments to the burner or its operating settings.

4.1.1. Simulator Test Results

All water heater burners and their pilot lights were consistently able to operate with natural gas and 0 to 30% mixtures of hydrogen blended into methane. Ignition was not an issue with all mixtures and flashback was not observed. ULN burner #2 had a localized and slightly lifted flame in a region on the flame holder which became more pronounced with greater hydrogen fractions, though this did not present an observable operational issue.

For furnace "in-shot" burners, hot and cold starts were performed for both high and low firing cases. Within less than 0.3 s from the initiation of the ignitor, the flame typically reaches the full length of the viewing tube, though it required 2–5 s to reach an appearance of a steady flame. While the steady state flame structure appeared to be impacted by hydrogen blending, with a shortened flame with up to 30% hydrogen blended in, ignitions were not observed to differ in duration or nature with increasing hydrogen. No sustained issues were observed with startup over the range of firing rates and mixtures, both for cold and hot starts, though an intermittent stability issue determined to be an artifact of the test setup is discussed later.

Still images of the burners from all tests are shown in Figure 8, where for "blue" flames (pancake and in-shot) it is difficult to draw conclusions, though it is important to note that the shift in color between more teal and blue flames is unexplained and is likely influenced by lighting/camera factors. For radiant burners, ULN #1 and #2 water heater burners, the cooling of the burner is apparent with increasing hydrogen, as is the portion of ULN #2, which has a slightly lifted flame in the rear, closer to the ignitor, both attributed to the reduced heat output.

Figure 8. Still images of water heater and furnace burners during simulator testing.

For all water heater burners and most furnace burner test cases, there were no adverse combustion characteristics observed when the hydrogen content in the fuel was increased during the ignition of pilot/main burners. A typical ignition of the in-shot burner at high-fire and 30% H_2 mixture is shown in Figure 9. The exception was one stability issue intermittently observed, namely flashback with a 20 and 25% H_2 mixture, though this was determined to be an artifact of the simulator test setup. Initially when observed, subsequent efforts to re-create this flashback via rapid cycling of the burner were successful, but only every 5–10 on-cycles.

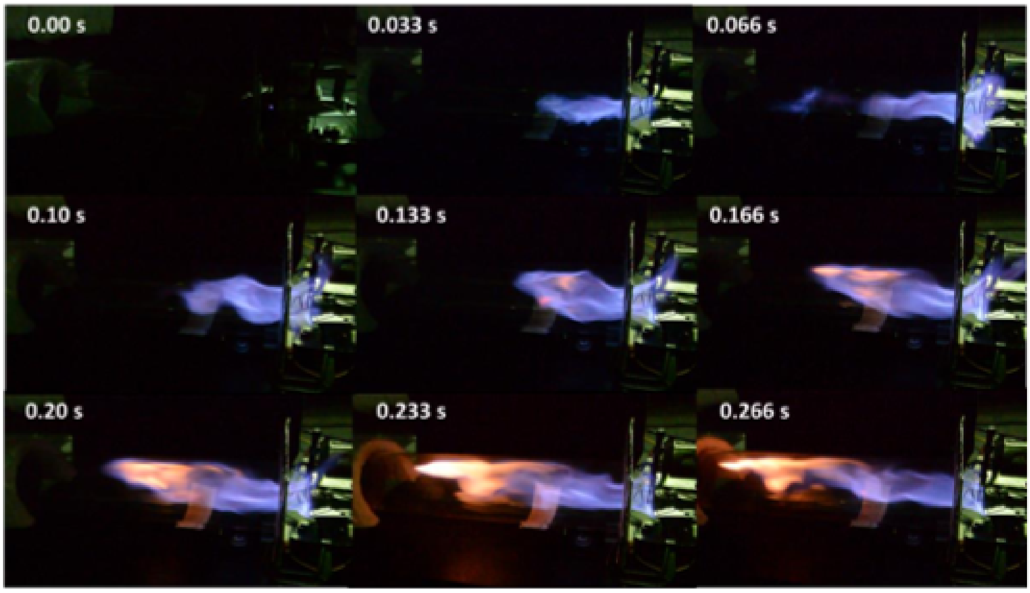


Figure 9. High-fire "hot" ignition of in-shot burner with 30% H_2 mixture.

The authors sought to recreate this flashback event systematically and isolate the impact of (a) duration between ignition calls when short-cycling and (b) the fuel mixture. A series of tests were repeated for natural gas, 10% hydrogen, 20% hydrogen, and 30% hydrogen, operating 10 sequential ignition cycles at high fire with a 15 s on-cycle and a range of delays between cycles of 2, 5, and 10 s. The inducer fan remained at the same setting as with prior testing. Finally, for the 30% hydrogen mixture only, the delay to energize the ignitor was varied between the default setting of 0.5 s up to 1.5 s. Over all conditions, flashback was not recreated, which suggests that other factors outside of burner operation, potentially including environmental factors, were responsible for the seemingly random flashback events. Despite the inability to systematically recreate flashback, initial observations confirm that the simple flow-through design of the "in-shot" furnace burners makes is more susceptible to flashback.

As expected, input rates were observed to decline with increasing hydrogen blends, with Figure 10 highlighting the decline for each water heater burner, with a scaled comparison of the calculated shift in WI. As with parallel studies, actual de-rating differs from the WI-based prediction, likely due to non-idealized hydrodynamics relative to orifice sizing practices. For the pancake burner and ULN burner #2, both radial burners with the orifice assembly within the combustion chamber, the WI-based prediction underestimates the de-rating suggesting the addition of hydrogen has a non-linear impact on burner fuel and air flow. By contrast, for the ULN #1 burner with its ample and rectilinear flow path and orifice assembly external to the combustion chamber, the WI-based prediction overestimates de-rating, suggesting that these dynamics are less important. Furnace de-rating from simulator tests does not show consistent declines, due to the constant inducer fan and artifacts of the simulator design, with high-fire and low-fire input rates only decreasing between 0 and 30% H_2 by 1.4 and 1.9%, respectively. The heat input rate was obtained by taking the average of the stabilized fuel flowrate measurements. Therefore, the experiment error was mainly from the Elster DTM-200A Gas Meter, which was ±1% of the heat input rate readings.

Regarding the NO_x and CO emissions in Figures 11 and 12, water heater and furnace burners show moderate shifts in CO emissions and declines in NO_x emissions with increasing hydrogen blended, owing in the large part to the excess air dilution impacts. In terms of magnitude with the data shown below for the three burners, the one exception is ULN #2 with CO emissions, showing slightly greater than ±1 10 ppm air free (AF) CO, which may be due to observed localized flame lifting. Furnace in-shot burners show similar increases in CO emissions from 25 to 30% H_2. Measured NO_x emission levels of the ULN burners were under 50 ppm; therefore, the accuracy was ±3 ppm of the analyzer readings. The pancake burner and the in-shot burner NO_x emission levels were above 50 ppm. Therefore, their emission levels were ±5% of the readings. ULN #2 burner had the highest CO emissions, which had an accuracy range of ±5% of the readings. The measurement accuracy of the rest burners was ±10 ppm. It should be noted that the emission analyzer and sampling system was not optimized for ultra-low NO_x measurements, and so unaccounted for uncertainties for ULN #1 and ULN #2 water heaters may still be present.

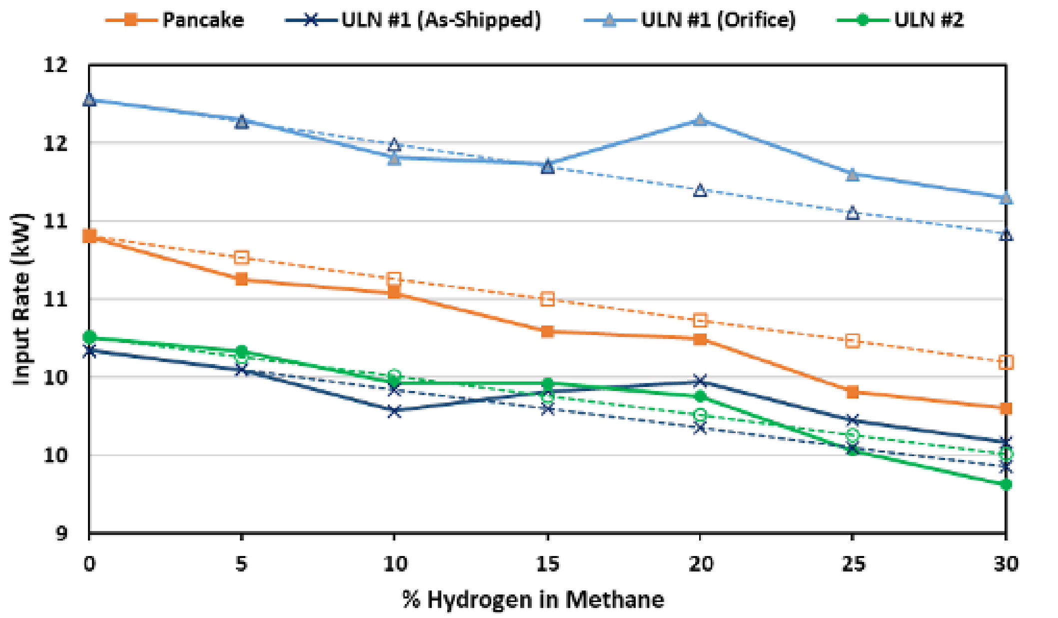


Figure 10. De-rating of water heater burners as measured (solid lines) and compared to Wobbe Index shift calculation (dashed lines).

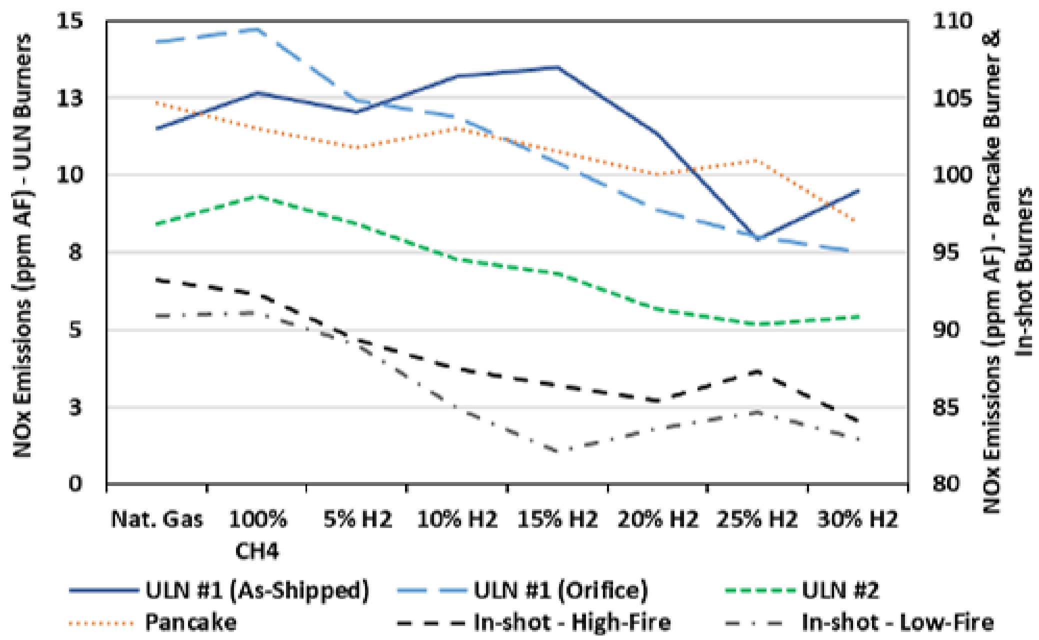


Figure 11. NO_x emissions (air-free) for simulator tests.

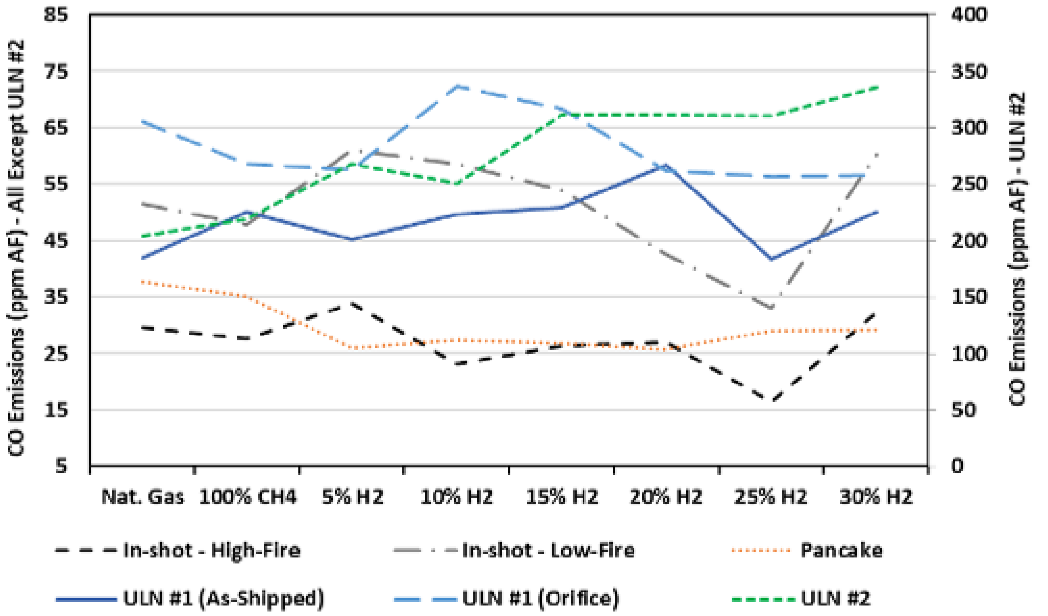


Figure 12. CO emissions (air-free) for simulator tests.

4.1.2. In Situ Test Results

For water heater testing, as with open air testing, there were no observable issues with ignition from a cold start or hot cycling for the three water heaters from 0 to 30% hydrogen, with pilot lights functional over the full range as well. When observed in the open air, with examples in Figure 13, ULN water heater #2 did not have the same noticeable lifted flame portion towards the burner rear while operating within the water heater seen in the figure below, suggesting this was largely an artifact of the simulator operation itself (e.g., insufficient draft through the burner inlet).

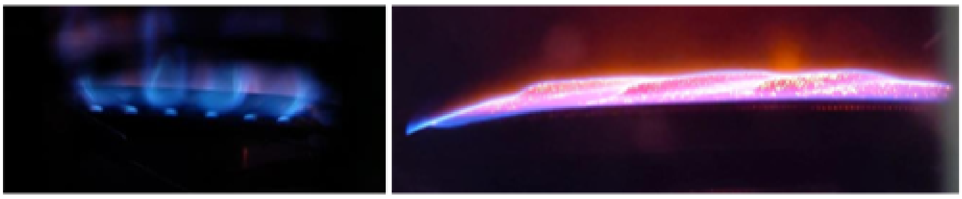


Figure 13. Standard water heater (**Left**, Steady State) and ULN Water Heater #2 (**Right**, 30 s After Ignition) operating in situ with 30% H_2.

For both furnaces over all conditions tested, the cold and hot startups were successful except for one instance of flashback, due to an operational error. Ignitions were successful and there was no discernable difference between the natural gas, 100% methane, and 30% hydrogen blended fuels, although the visual access was much more limited than simulator testing, as seen in Figure 14. According to the images below, the condensing furnace combustion was not noticeably different across the range of fuels used, for example. In the instance of flashback, the system was operating with natural gas, shut down, then switched to a 5% hydrogen mixture. Typically, there would be a purge time between switching fuels of ~1 min, followed by operating the system. During the purge time between natural gas and 5% hydrogen/methane, the flame receded to the orifice for ~20 s, after which the flame returned to stabilize at the flame holder at the end of the burner. There were abnormalities with recorded measurements, such as inlet pressure, suggesting that there was a test rig malfunction, and despite repeated attempts to recreate this flashback via transition from natural gas to 5% hydrogen blended fuel, this flashback event was not repeated. While inconclusive, this suggests that furnaces may be more sensitive to rapid shifts in hydrogen content than water heaters, which is worthy of subsequent investigation.

Further investigation into the combustion stability of in-shot burners is necessary, but was beyond the scope of this study.

Figure 14. Visualization of condensing furnace burners at a steady state.

Concerning ignition, most furnaces use a "rolling ignition", wherein one burner is ignited and the flame "rolls" across the other burners to compete ignition. This sequence is clear from the images below in Figure 15 for the non-condensing furnace with a 30% hydrogen blend. Comparing across high vs. low fire, cold vs. hot start, and a range of fuel compositions, the timing of this rolling ignition was quantified, where cold starts, higher hydrogen blends, and high firing rates all tend to delay ignition across the four burners, with a maximum increase of 233 ms from 5% H_2 to 30% H_2 observed for the right-most burner. Visual access prevented a similar analysis of the condensing furnace, in addition to its use of multiple ignition points.

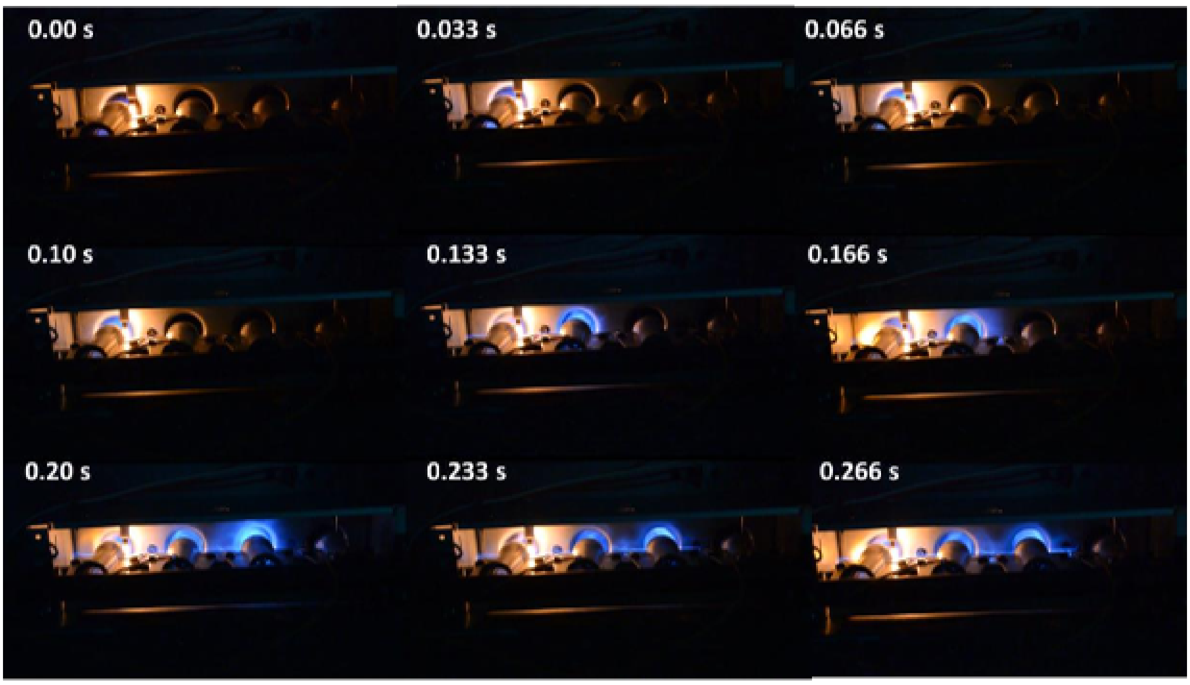


Figure 15. Rolling ignition of a non-condensing furnace at a 30% H_2 blend.

As anticipated, de-rating was observed for all water heaters from 0 to 30% hydrogen blends, ranging from 7.4% (ULN #1) to 9.1% (ULN #2) and 11.2% (Pancake). When comparing these values in Figure 16, the deviation from WI-based de-rate tightens. In the case of ULN #1, it shows a near perfect prediction of de-rating with the WI. As with the individual burners being tested, the experimental error was from the Elster DTM-200A Gas Meter, which was ±1% of the heat input rate readings. Both the pancake and ULN #2 type water heaters show slight underprediction of de-rating by the WI decline, though the difference is smaller than that of open-air burners. A key distinction between the ULN #1 burner and the other burners in this study is that the orifice ejecting fuel is positioned outside of the combustion chamber, a feature clear from the burner photos in Figure 5. By contrast, the orifice for the "pancake" burner is wholly within the chamber and for the ULN #2 burner is exposed to the ingested primary air. This points to a difference in the static pressure inside the combustion chamber and at the gas orifice, which explain the differing observations. The static pressure inside the water heater combustion chamber was not measured, so this hypothesis remains to be confirmed. Capacity decline with hydrogen blending for furnaces was not steady, though an overall decline of 7.8% for the condensing furnace and only 2.3% for the non-condensing furnace, from 0 to 30% H_2, respectively, was observed. A subsequent investigation is needed to study the impact of furnace operation as a function of inducer fan settings for single-stage, multi-stage, and modulating furnaces.

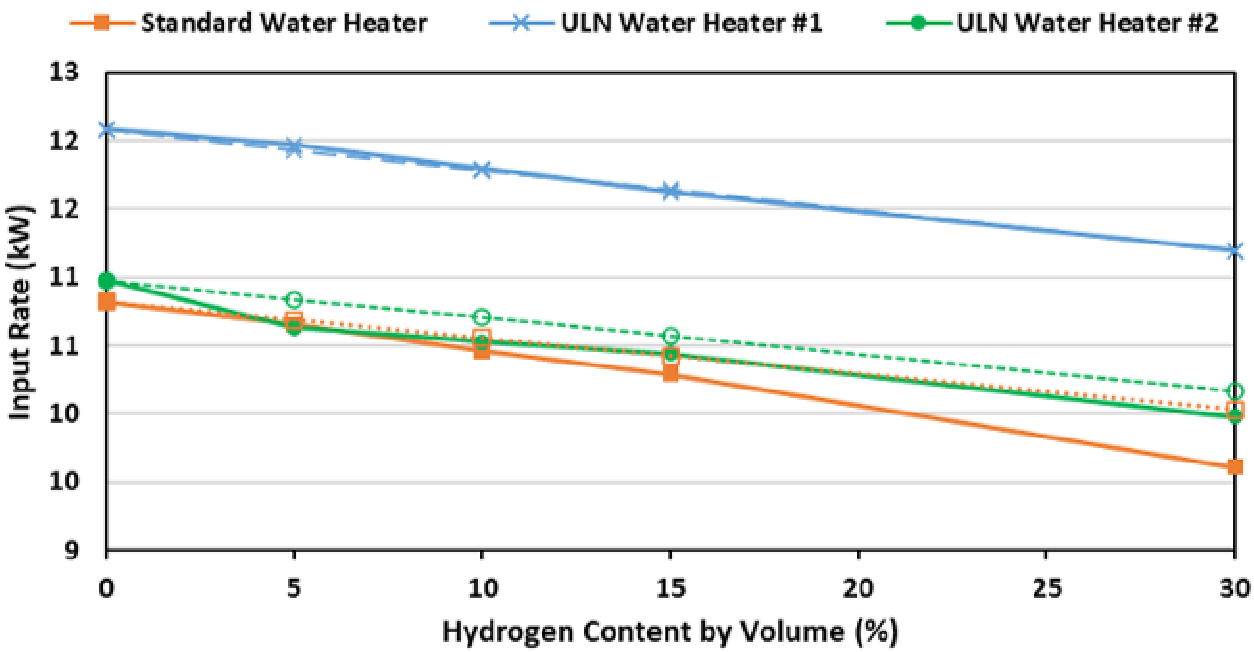


Figure 16. De-rating of water heaters as-measured (solid) and comparing to Wobbe Index shift calculation (dashed).

Regarding emissions, CO declined or remained flat for the pancake and ULN burner #1 type water heaters within narrow ranges. For the ULN burner #2 type water heater, a steady increase in CO emissions from 30 to 63 ppm AF was observed, though emissions were well below the allowable 400 ppm AF for certification via ANSI Z21.10.1. For the furnaces, the O_2 and CO_2 showed increasing dilution, from 0 to 30% H_2 blends, with CO_2 from 7.5 to 5.9% (condensing) and 6.5 to 3.7% (non-condensing high-fire). For both furnaces, a moderate increase in CO emissions was observed, at 50 ppm AF (condensing) and 10 ppm AF (non-condensing high-fire). For NO_x emissions, a consistent decline was observed with all water heaters, reducing both ULN burner NO_x emissions by approximately half, while furnaces showed a similar but less pronounced decline, as plotted in Figure 17. The CO/NO_x emission measurement accuracy was consistent with the individual burner testing. For the condensing furnace, a moderate increase (~5 °C) in burner surface temperatures up to the 30% hydrogen blend was observed, while a small decrease (~2.5 °C) was seen with the non-condensing furnace at high-fire over the same range. The temperature measurement accuracy range was ±0.5 °C. More significant shifts in surface temperatures were observed with the natural draft water heaters, as shown in Figure 18, where steady declines were observed for the radiant ULN #1 burner, while the standard pancake burner showed increases.

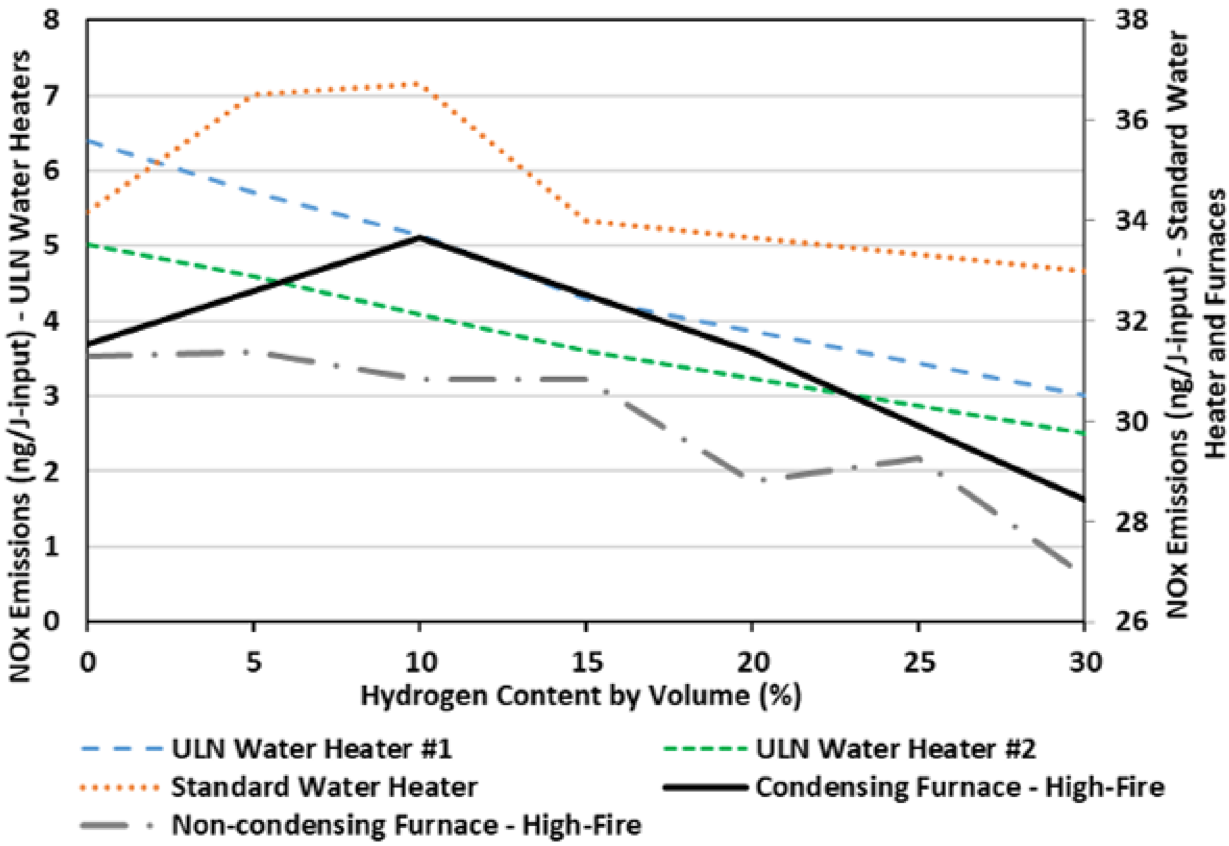


Figure 17. NO_x emissions (ng/J-input) for in situ tests.

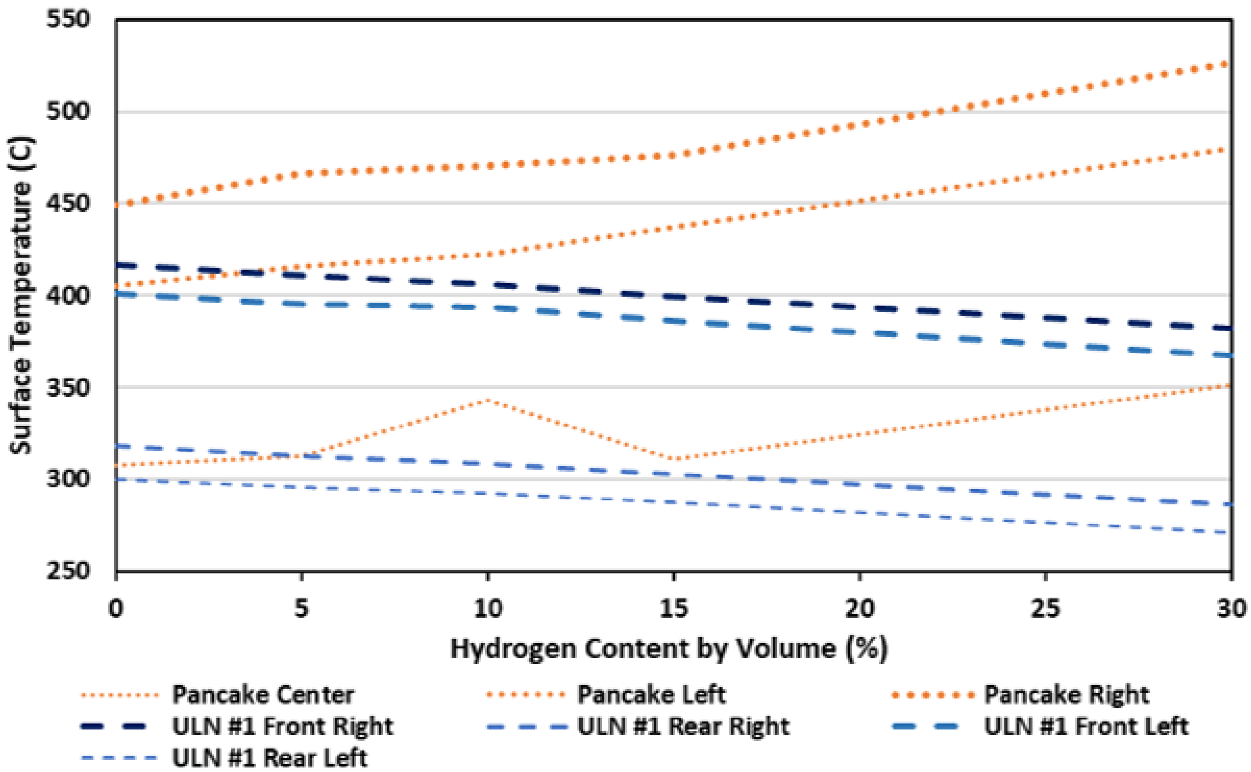


Figure 18. Burner surface temperatures during water heater in situ tests.

For the standard water heater and ULN water heater #1, the recovery efficiency test was performed as defined in the U.S. Dept. of Energy test method, which calculates an equivalent steady-state efficiency during storage tank reheating as the recovery efficiency as summarized in Figure 19. This efficiency is used in place of the true steady-state efficiency in the calculation of the uniform energy factor (UEF). Additionally, during this test, exhaust temperature and flue-gas composition were used to estimate the excess aeration. Note that for the standard water heater, the recovery duration for the 30% hydrogen blend increased by 10.4%, while the ULN water heater #1 ran for 20.7% longer (an artifact of the recovery efficiency procedure). Shifting from 100% methane to 30% hydrogen/70% methane increased the measured total excess air and decreased the flue gas temperatures. For the standard water heater, the impact of dilution was apparent as a minor efficiency penalty counteracting the expected improvement in efficiency due to de-rating. For the ULN #1 burner, a radiant burner in contrast to the "pancake" burner, the radiant heat transfer may be improved with the 30% hydrogen case in addition to the overall reduced excess aeration. Additionally, the greater increase in recovery time for the ULN water may also play a role in progressing toward steady-state operation. It should be noted here that the temperature measurement accuracy was ±0.5 °C, and the excess air level error was under ±3% (contributed by oxygen measurement). Therefore, the efficiency variation from 100% methane to 30% hydrogen/70% methane was within the measurement accuracy range.

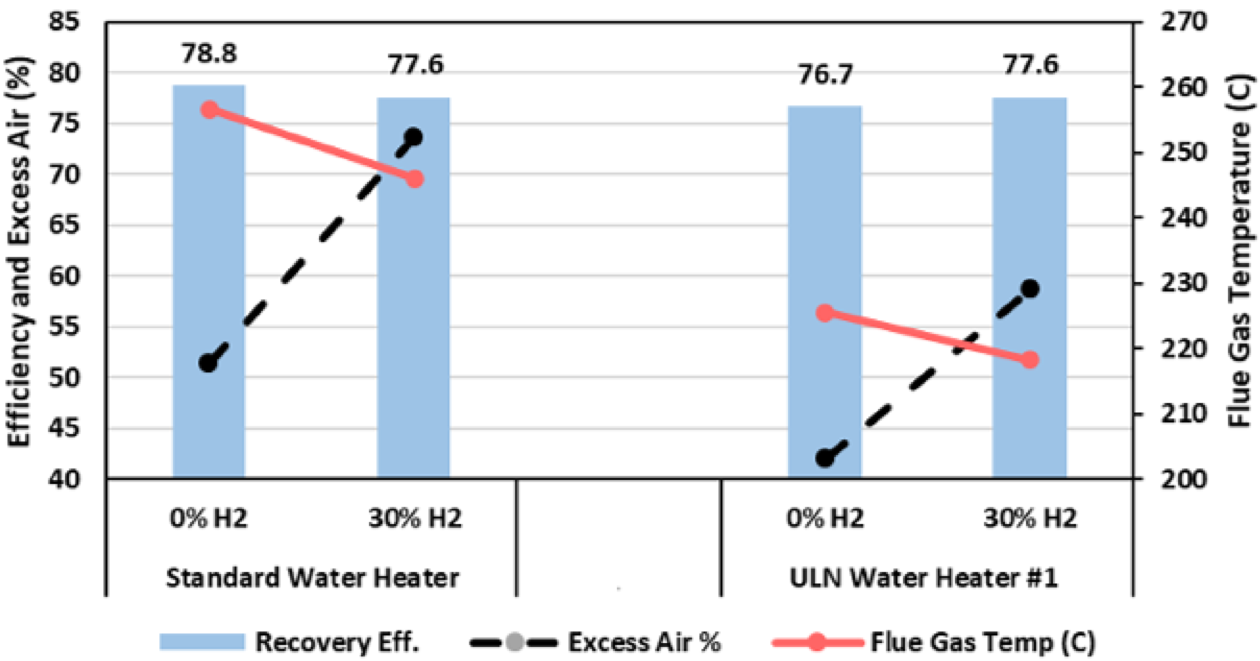


Figure 19. Impact of hydrogen blending on water heater efficiency, excess air, and flue gas temperature.

For the "slug test", the standard water heater and ULN water heater #1 were operated with a 5% hydrogen mixture, then rapidly shifted to a 30% mixture, repeating this cycle while the unit was operating. The plots in Figures 20 and 21 show the results for this test, with the sharp rise and decline in O_2 (inverse for CO_2) as the hydrogen concentration was shifted, with a tandem fall and rise in flue gas temperatures. For the "pancake" burner, the CO and NO_x emissions were not significantly impacted in this shift, while they were for the ULN water heater. Throughout the "slugs" shifting from 5 to 30%, there was no noticeable impact on the stability of the flame and equipment operation.

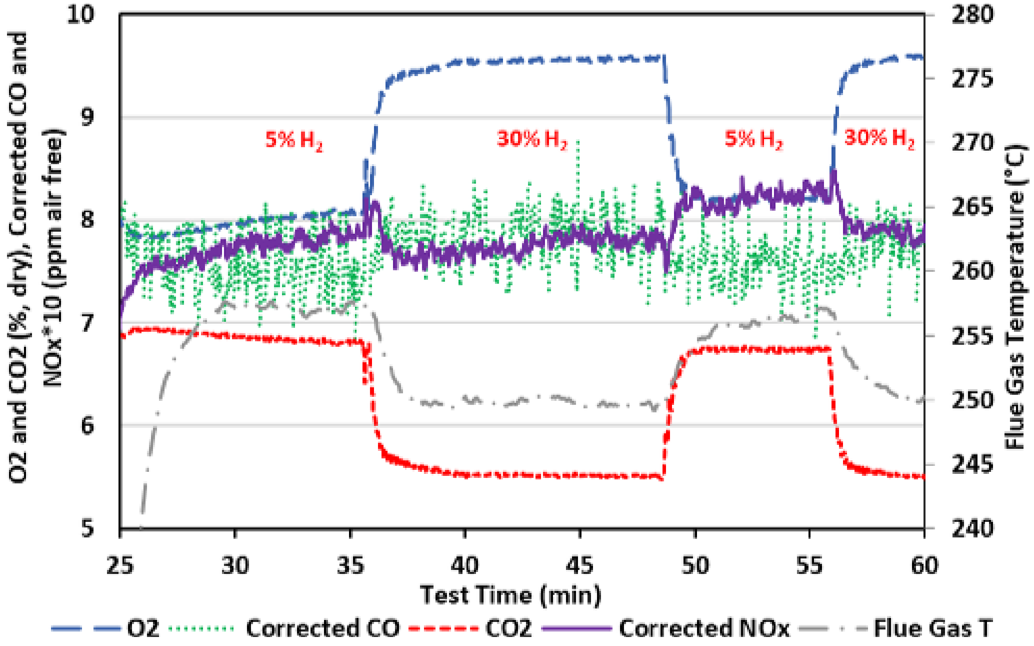


Figure 20. Slug test results for standard water heater.

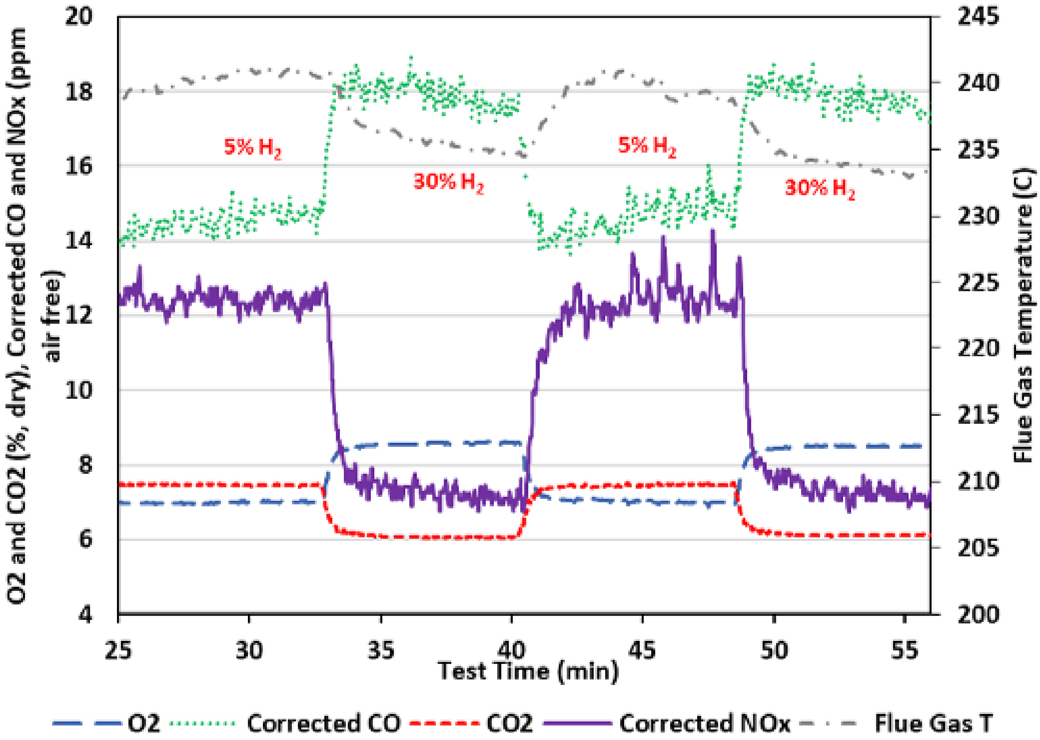


Figure 21. Slug test results for ULN water heater #1.

4.2. Field Equipment Sampling

Within the limitations of the field measurements, no significant difference in NO_x emissions was observed between natural gas and hydrogen mixtures. There were other factors outside of the control of this study, such as ambient temperature, humidity, and other weather conditions that may have affected the results.

Figure 22 shows the NO_x emissions of representative appliances operating using natural gas and natural gas/hydrogen mixtures. Generally, the 5% hydrogen addition to natural gas did not influence the NO_x emissions for these appliances.

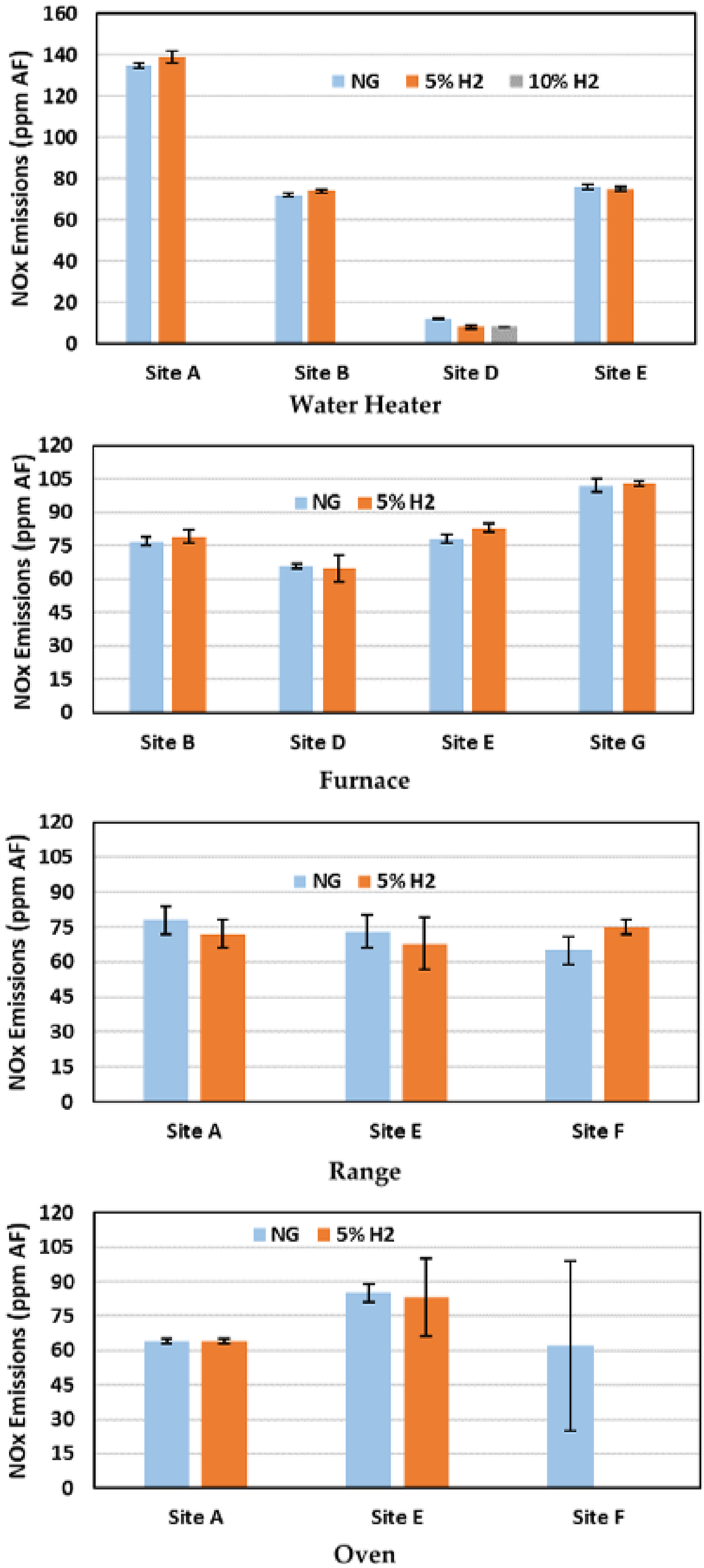


Figure 22. NO_x emissions of field-sampled equipment.

For the water heater at Site A, which was a manufactured housing-type water heater, the NO_x emissions were the highest, reaching 140 ppm in air-free conditions. The water heaters at Site B and E were conventional storage water heaters, and the NO_x emissions of these water heaters were around 75 ppm. The water heater at Site D was an ultra-low NO_x variety, which had the lowest NO_x emissions level (<10 ppm) among all appliances tested.

Warm-air furnaces at four testing locations had relatively similar NO_x emissions. The furnaces at Site B, D and E had NO_x emissions under 80 ppm. The highest NO_x emissions of furnaces were from Site G, which was a natural draft wall furnace.

Range cooktop and oven emissions were also collected. The NO_x emissions of these burners were similar among various testing sites. It should be noted that kitchen flames are usually less enclosed compared to water heaters and furnaces; therefore, the error of the emission readings are larger.

The results from sampling dryers were not reported. Due to the high dilution rate of the exhaust (~20% O_2 in the sample), the emission readings were outside of reportable accuracy. According to visual observation, it is believed that 5% hydrogen addition did not have significant impacts on the performance of the dryers. It is suggested that future dryer emission testing requires accessing the burner assembly. The fireplace emissions measurement had a similar problem. The measured NO_x emissions of the fireplace were around 10 ppm with a high dilution, and therefore, more data need to be collected on fireplaces. No evidence was observed that shows that hydrogen addition had any significant influence on CO emissions from the appliances tested.

5. Summary

5.1. Conclusions

In this effort and following a thorough review of the current state of knowledge, the authors sought to better characterize the impacts of hydrogen-blended natural gas up to 30% by volume on common partially premixed combustion equipment, including water heaters, furnaces, and miscellaneous appliances, from a whole equipment point of view and concerning the burners used. Through laboratory testing, using purpose-built "simulators" and in situ tests, and field sampling in a simulated operating environment, a series of short-term tests were performed on these components and equipment with the aim of characterizing performance, efficiency, emissions, and other factors as a function of hydrogen blending up to 30% by volume. In general, all appliances and their burners were able to tolerate this shift in fuel composition, without notable excursions in process temperatures or emissions, and anticipated trends were confirmed and further quantified for these appliances, ranging from the de-rating of heat input, to the increase in excess aeration, and to the NO_x and CO emissions. For these unadjusted, partially premixed type combustion appliances, the dominant impact of hydrogen blending is the increase in excess air, often resulting in lower NO_x emissions, surface temperatures, and other parameters.

The authors emphasize that these findings, if generalized, only apply to natural-gas appliances from mainland United States and Canada, and are as follows:

1. The combustion stability of the burners and appliances tested was not impacted by up to 30% of H_2 by volume, as evidenced by lack of flashback, flame lift, and CO emissions above 400 ppm AF.
2. While de-rating of appliances can be approximated by the WI comparison, it is not exact and higher levels of de-rate are likely to be observed in the field.
3. The efficiency of the appliances tested only varied by ~1–1.5% with 0 to 30% hydrogen-blended fuels, which is consistent with prior observations, though the changes in flue gas temperature and excess aeration did not always point to the same result. The overall efficiency ratings should be investigated in more detail; the decarbonization benefit of H_2 blending can be decreased or increased by changes in appliance efficiency.
4. Within the limits of the instrumentation and procedures used, NO_x emissions from laboratory and field measurements point to either no change or a decrease with increasing blends of hydrogen up to 30% by volume.

5. The most sensitive burners to hydrogen blending were of the "in-shot" variety, used by warm-air furnaces, tested in the laboratory. Flashback events observed were inconsistent and likely caused by either test procedures or sensitivities of the specific test stands used. Further investigation into these burners is recommended.

In broader terms, other follow-on research is recommended concerning the nuances amongst equipment and between blending levels, including (a) the atypical de-rating behavior of the non-condensing furnace, (b) disaggregating the impact of hydrogen on radiant burner output, (c) characterizing the nature and impact of ignition timing, (d) generalizing the impact of hydrogen on specific burner design features (e.g., key dimensions), (e) examining the errant flashback events observed during testing, and (f) establishing actual blend limits for the variety of partial-premixed burners and appliances in use.

5.2. Recommendations

Concerning the decarbonization of gas grids using hydrogen, a broader issue remains that the industry's knowledge of how hydrogen-blended natural gas impacts the wide diversity of stationary combustion equipment is based on a limited dataset. For residential and commercial buildings, the authors recommend expanding investigations similar to this effort in the following ways, to:

1. Expand the dataset: further quantify the emissions, efficiency, and safety impacts on a wider range of equipment types, including a greater diversity of water and space heating equipment, cooking equipment, and other miscellaneous fuel-fired appliances. Additionally, expand the scope of testing, including higher hydrogen blends, the impact of the balance fuel (e.g., natural gas), indoor and equipment component, new versus aged equipment, emerging technologies (e.g., fuel-fired heat pumps), and explore the operating envelope (fuel pressure, over/under-firing, venting matters, environmental conditions, etc.).
2. Quantify long-term impacts: long-term impacts are even more poorly understood, ranging from hydrogen-blended natural gas impacts on equipment operating life, maintenance needs, material and component degradation, and on the infrastructure (e.g., piping, venting).
3. Gain experience in the field: true in situ testing will be valuable in the field, to verify laboratory-based findings, in addition to (a) quantifying impacts on installation, operation, and maintenance of equipment, (b) establishing best practices concerning re-commissioning and troubleshooting equipment issues, (c) implementing simple retrofit packages to enable hydrogen-blended fuel tolerance, and (d) establishing the use case(s) for enhanced sensors for equipment and building systems.
4. Modernize codes and standards: to operate the equipment in this study with a 30% hydrogen/natural gas blend is to go outside its certification for safety, performance, and possibly efficiency and emissions. Modernization of these associated codes and standards is essential in parallel to expanding these laboratory and field datasets.

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Appendix A

This informative appendix provides an overview of the fuel gas quality impacts of hydrogen blended into natural gas. In practice, the effect of increasing the quantity of hydrogen blended into natural gas on equipment is highly equipment-specific. However, general trends from the fuel properties can be illustrative. For hydrogen blended into methane, >95% of delivered natural gas in North America [25], key gas quality metrics are shown in Figure A1 as a function of hydrogen blended by volume.

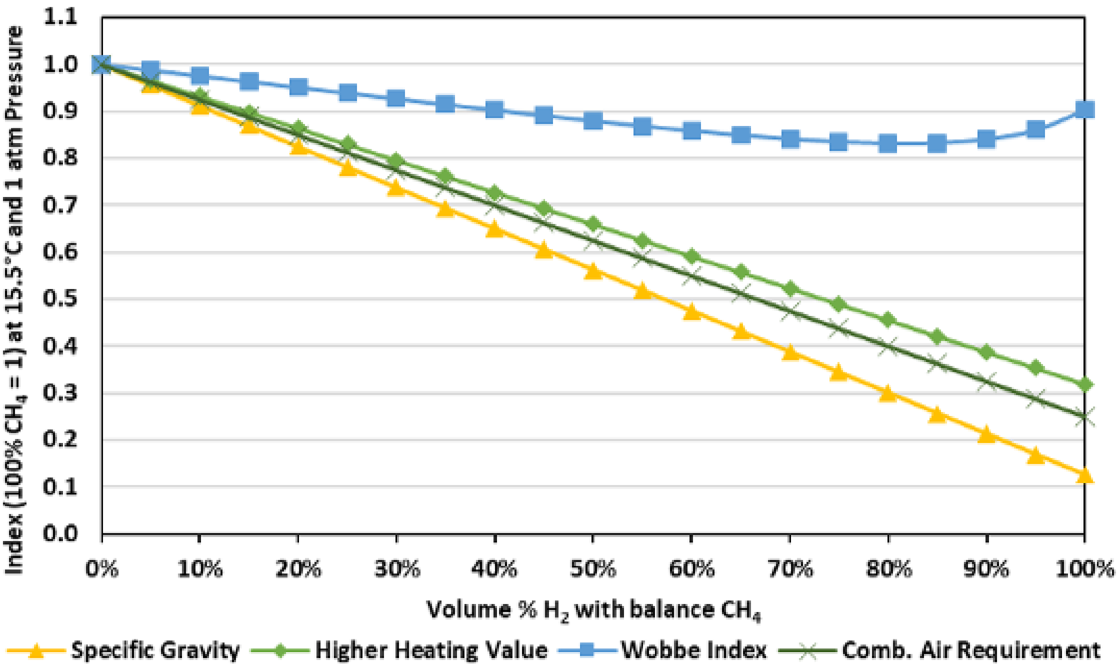


Figure A1. Impact of hydrogen blended into methane on key gas quality properties.

For equipment operating on distribution networks maintained at low pressures, typically 34 to 138 mbar delivered for typical homes and businesses, the most significant impact is the reduced volumetric density, as specific gravity (SG) is reduced by 17% for a 20% hydrogen blend and by 87% for pure hydrogen, where values for natural gas are typically 0.60 to 0.70. Similarly, the higher heating value (HHV) is reduced by 14% for a 20% hydrogen blend and 68% for pure hydrogen, driven by this volumetric density impact. A commonly used metric to judge the interchangeability of gaseous fuels, the Wobbe Index (WI), is defined in Equation (A1). As shown in Figure A1, WI is stable over the range of hydrogen addition, reducing by only 5% for a 20% hydrogen blend and by 10% for pure hydrogen. In practice, fuels with the same WI should yield the same heating rate for a given appliance with a fixed orifice pressure. However, it is imperfect for predicting the response from equipment with modern combustion controls or for certain fuel mixtures.

Analogous to the WI, the combustion air requirement (CAR), as defined in Equation (A2), posits that for appliances without active control of the air-to-fuel ratio, representing the majority of those in buildings, the actual air-to-fuel ratio is assumed to be a function of the fuel density alone for a given appliance with a fixed orifice pressure, and thus the excess aeration can be predicted for a change in fuel as the product of the air-to-fuel equivalent ratio (λ), and this index is assumed to be constant. From Figure A1, the stoichiometric combustion air-to-fuel ratio declines significantly, by 15% with a 20% hydrogen blend and by 75% for pure hydrogen, indicating the sharp reduction in combustion air necessary for hydrogen versus methane. Note that as with the WI, the CAR is imperfect in its predictive accuracy, as fuel and air mixing is a complex, turbulent process influenced by changes in fuel viscosity and other properties. The fact that hydrogen addition impacts λ is fundamental, making subsequent predictions of flame speed, emissions, and other impacts very difficult.

$$\text{Wobbe Index} = {}^{\text{HHV}}/_{\sqrt{\text{SG}}}, \quad (A1)$$

$$\text{Combustion Air Requirement} = \frac{(\text{Air to Fuel Ratio})_{\text{stoichiometric}}}{\sqrt{\text{SG}_{\text{fuel}}}}, \quad (A2)$$

It is important to emphasize the nuances of CO_2 emission reduction from blending hydrogen into natural gas, as hydrogen is primarily viewed as a decarbonization vector. In Figure A2, the following illustrative comparison is made, examining the impact of normalizing to a volume, mass, or energy basis.

1. Scaling to a mass basis is not common, as the delivered fuel is measured on a volumetric basis (ft^3, m^3). Nonetheless, hydrogen's significantly higher energy density on a mass basis (e.g., Btu/lb, MJ/kg) is shown to increase by more than 2.5 times for pure hydrogen. However, when plotted as a function of volume of hydrogen added (horizontal axis), the CO_2 emission factor on a mass basis is highly non-linear.
2. Scaling to a volumetric basis is appropriate in some circumstances, and with zero on-site CO_2 emissions from hydrogen, the emission factor declines proportionately with blending (e.g., 10% blend reduces CO_2 emissions by 10%). In practice, this is only appropriate when there is not manual or automatic compensation for the reduced heating rate (e.g., decorative gas fixtures).
3. Scaling to an energy basis is appropriate in most cases, where the fuel-fired equipment manually or automatically compensates for the reduced heating rate. For example, in a furnace operating normally as controlled by a thermostat for a given heat demand, the furnace will consume more blended fuel with longer operating times to compensate for the fuel's reduced heating value, yielding a net CO_2 reduction of 7.2% at 20% H_2 (energy basis).

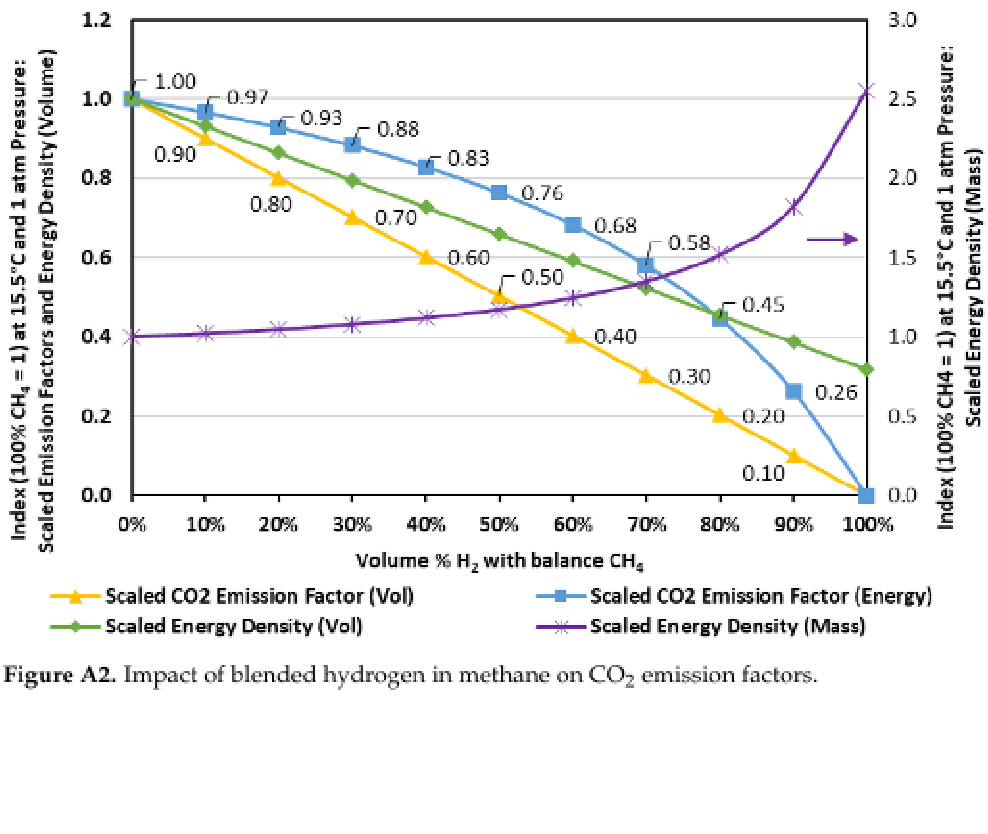


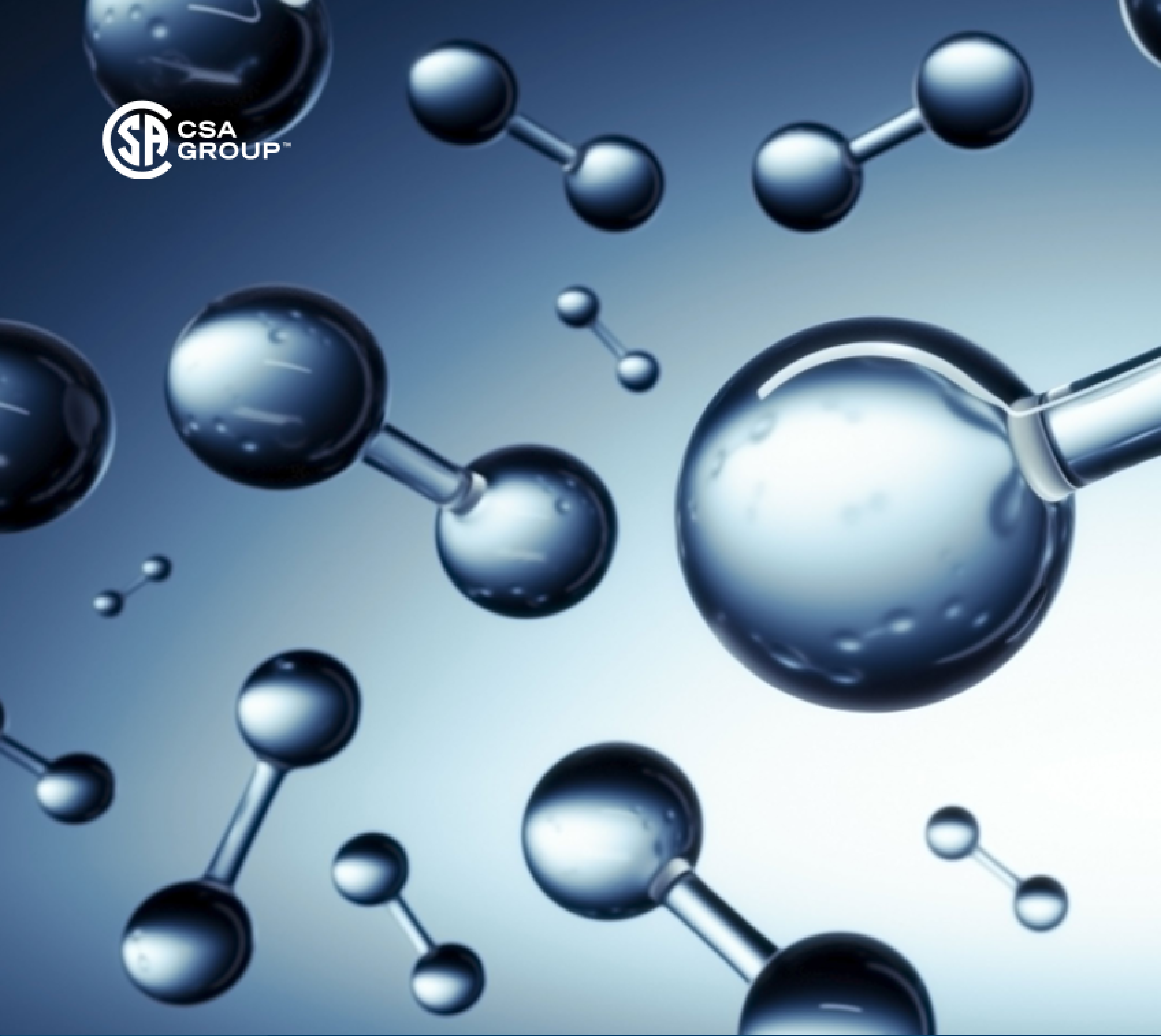
Figure A2. Impact of blended hydrogen in methane on CO_2 emission factors.

Note that this discussion neglects any upstream CO_2 emissions in hydrogen production, transmission, and distribution, in the same manner as for "site" electricity. Additionally, testing is necessary to assess the CO_2 emissions reduction from specific equipment, as the operating efficiency has been shown to be impacted by changes in the fuel mixture [22,23], as shown in this paper.

References

1. Natural Resources Canada (NRCan). Hydrogen Strategy for Canada: Seizing the Opportunities for Hydrogen. 2020. Available online: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf (accessed on 12 December 2021).
2. U.S. Department of Energy (DOE). Secretary Granholm Launches Hydrogen Energy Earthshot to Accelerate Breakthroughs Toward a Net-Zero Economy. Available online: https://www.energy.gov/articles/secretary-granholm-launches-hydrogen-energy-earthshot-accelerate-breakthroughs-toward-net (accessed on 12 December 2021).
3. U.S. Energy Information Administration (EIA). Natural gas explained. Available online: https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php (accessed on 12 December 2021).
4. Canadian Gas Association (CGA). Natural Gas Statistics. Available online: https://www.cga.ca/natural-gas-statistics/ (accessed on 12 December 2021).
5. Lawrence Livermore National Laboratory (LLNL). Carbon Flow Charts. Available online: https://flowcharts.llnl.gov/commodities/carbon (accessed on 12 December 2021).
6. Canadian National Energy Use Database (NEUD). NEUD Tables. Available online: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/databases.cfm (accessed on 12 December 2021).
7. Fuel Cell and Hydrogen Energy Association (FCHEA). Road Map to a US Hydrogen Economy. 2020. Available online: https://www.fchea.org/us-hydrogen-study (accessed on 12 December 2021).
8. Fuel Cells and Hydrogen—Joint Undertaking (FCH-JU). Hydrogen Roadmap: Europe. 2019. Available online: https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition (accessed on 12 December 2021).
9. Saeedmanesh, A.; MacKinnon, M.; Brouwer, J. Hydrogen is Essential for Sustainability. *Curr. Opin. Electrochem.* **2018**, *12*, 166–181. [CrossRef]
10. Institute of Gas Technology (IGT). *A Hydrogen–Energy System*; Report prepared for the American Gas Association; Catalog No. L21173; Institute of Gas Technology: Des Plaines, IL, USA, 1972.
11. Tarr, J. Transforming an Energy System: The Evolution of the Manufactured Gas Industry and the Transition to Natural Gas in the United States (1807–1954). In *The Governance of Large Technical Systems*; Coutard, O., Ed.; Routledge: London, UK, 1999; pp. 19–37.
12. ATCO Gas. Fort Saskatchewan Hydrogen Blending Project. Available online: https://www.atco.com/content/dam/web/projects/projects-overview/fort-sask-hydrogen-blending-info-sheet.pdf (accessed on 12 December 2021).
13. Enbridge Gas. Clean Hydrogen Enters the Markham Energy Mix. Available online: https://www.enbridge.com/stories/2022/january/hydrogen-blending-project-enbridge-gas-cummins-operational-markham-ontario (accessed on 9 December 2021).
14. SoCalGas. Prepared Direct Testimony of Kevin Woo, David McQuilling, and Kevin Lang. Available online: https://www.socalgas.com/sites/default/files/2020-11/H2_Application-Chapter_4-Technical.pdf (accessed on 9 December 2021).
15. Dominion Energy. Hydrogen. Available online: https://www.dominionenergy.com/projects-and-facilities/hydrogen (accessed on 9 December 2021).
16. NW Natural. VISION 2050: Destination Zero. Available online: https://www.nwnatural.com/-/media/nwnatural/pdfs/vision2050bronov2021final.pdf?la=en&hash=85E02B181494D79DD7F2225778612E47 (accessed on 9 December 2021).
17. Hawaii Gas. Synthetic Natural Gas (SNG). Available online: https://www.hawaiigas.com/clean-energy/synthetic-natural-gas/ (accessed on 12 December 2021).
18. Melaina, M.; Antonia, O.; Penev, M. *Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues*; Technical Report NREL/TP-5600-51995 prepared under Contract No. DE-AC36-08GO28308 for the U.S. Dept. of Energy; National Renewable Energy Laboratory: Golden, CO, USA, 2013.
19. Needley, P.; Peronski, L. *Assessment of Hydrogen Enriched Natural Gas*; Report AHRI-8024 prepared for the Air-Conditioning Heating and Refrigeration Institute; Air-Conditioning Heating and Refrigeration Institute: Arlington, VA, USA, 2021.
20. De Vries, H.; Florisson, O.; Thiekstra, G.C. Safe Operation of Natural Gas Appliances Fueled with Hydrogen/Natural Gas Mixtures (Progress Obtained in the NaturalHy-Project). In Proceedings of the International Conference on Hydrogen Safety, San Sebastian, Spain, 11–13 September 2007.
21. Schaffert, J.; Fischer, P.; Leicher, J.; Burmeister, F.; Flayyih, M.; Cigarida, H.; Albus, R.; Görner, K.; Mili, P.; Carpentier, S.; et al. Impact of Hydrogen Admixture on Combustion Processes—Part II: Practice. Deliverable D2.3 as Submitted from the THyGA Project. 2020. Available online: https://thyga-project.eu/wp-content/uploads/20201211-D2.3-Impact-of-Hydrogen-in-Practice_final.pdf (accessed on 12 December 2021).
22. McDonell, V.; Zhao, Y.; Choudhury, S. *Implications of Increased Renewable Natural Gas on Appliance Emissions and Stability*; Report CEC-500-2020-070 prepared for the California Energy Commission under Contract PIR-16-017; California Energy Commission: Sacramento, CA, USA, 2020.

23. Suchovsky, C.J.; Ericksen, L.; Williams, T.A.; Nikolic, D.J. *Appliance and Equipment Performance with Hydrogen-Enriched Natural Gases*; Report prepared for the Canadian Standards Association; Canadian Standards Association: Toronto, ON, Canada, 2021.
24. Glanville, P.; Fridlyand, A.; Keinath, C.; Garrabrant, M. Demonstration and Simulation of Gas Heat Pump-Driven Residential Combination Space and Water Heating System Performance. *ASHRAE Trans.* **2019**, *125*, 264–272.
25. Southwest Research Institute. *Compressed Natural Gas Vehicle Fuel Survey*; Report prepared for the CRC under Project No. PC-2-12; Southwest Research Institute: San Antonio, TX, USA, 2014.
26. Choudhury, S.; McDonell, V.; Samuelsen, S. Combustion performance of low-NOx and conventional storage water heaters operated on hydrogen enriched natural gas. *Int. J. Hydrog. Energy* **2020**, *45*, 2405–2417. [CrossRef]
27. Zhao, Y.; McDonell, V.; Samuelsen, S. Assessment of the combustion performance of a room furnace operating on pipeline natural gas mixed with simulated biogas or hydrogen. *Int. J. Hydrog. Energy* **2020**, *45*, 11368–11379. [CrossRef]
28. Zhao, Y.; McDonell, V.; Samuelsen, S. Influence of hydrogen addition to pipeline natural gas on the combustion performance of a cookop burner. *Int. J. Hydrog. Energy* **2019**, *44*, 12239–12253. [CrossRef]
29. Jones, H.R.N. Chaper 3—Partially aerated burners. In *The Application of Combustion Principles to Domestic Gas Burner Design*; E. & F.N.Spon: London, UK, 1990; pp. 30–75.
30. Pritchard, R.; Guy, J.J.; Connor, N.E. Chapter 7—Gas burners and burner systems. In *Handbook of Industrial Gas Utilization: Engineering Principles and Practice*; Van Nostrand Reinhold Company: New York, NY, USA, 1977; pp. 216–313.
31. Glassman, I.; Yetter, R.A. Appendix F—Laminar Flame Speeds. In *Combustion*, 4th ed.; Elsevier: Amsterdam, The Netherlands, 2008; pp. 713–720.
32. Glassman, I.; Yetter, R.A. Chapter 8—Environmental Combustion Considerations. In *Combustion*, 4th ed.; Elsevier: Amsterdam, The Netherlands, 2008; pp. 409–494.
33. U.S. Department of Energy (DOE). Appliance and Equipment Standards Rulemakings and Notices—Consumer Water Heaters. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32 (accessed on 12 December 2021).
34. U.S. Department of Energy (DOE). Appliance and Equipment Standards Rulemakings and Notices—Consumer Furnaces. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=59&action=viewlive (accessed on 12 December 2021).



STANDARDS RESEARCH

Appliance and Equipment Performance with Hydrogen-Enriched Natural Gases

May 2021

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Table of Contents

Executive Summary

Mixing of hydrogen into natural gas, as a means of mitigating environmental concerns associated with the use of fossil fuels, poses a question of performance of appliances designed for use with natural gas, when fuelled by blends of hydrogen and natural gas. This study examines the performance of space and water heating appliances fuelled by methane as a natural gas proxy, and methane/hydrogen blends containing up to 15% hydrogen. The appliances were tested for input rate, ignition and burner operating characteristics, combustion products properties, and gas leakage, using three gas mixtures (pure methane, 5% hydrogen/methane blend, and 15% hydrogen/methane blend mixtures) per applicable CSA/ANSI Z21 series Standards. Effects of gas composition on furnaces were also tested for temperature rise and heating tube temperatures. Condensing appliances were additionally assessed for dew point temperatures and acidity. Overall, appliances showed no major operable issues and consistent trends of decreased heat output and CO_2 emissions with increase of hydrogen content in methane/hydrogen blends. Consequently, to meet the same heat demand, the appliances would need to operate for longer periods which would result in additional carbon dioxide emissions. However, the overall CO_2 emissions for the same heat output are still expected to be lower with the use of blends compared to natural gas. Carbon monoxide and nitrogen oxide measurements were in the acceptable ranges regardless of the type of fuel used. No consistent trends were observed for other measured properties, indicating that hydrogen mixtures up to 15% do not significantly affect these parameters. Future testing of gas blends containing 5% and 15% of hydrogen as examined herein, as well as higher hydrogen amounts, ought to incorporate natural gases to determine more representative results.

"As the amount of hydrogen determines both physical and chemical properties of hydrogen-enriched natural gases (HENG), the safety and suitability of different mixture compositions in residential applications are becoming a focus of interest."

1 Introduction

Natural gas is overall the most common energy source for space heating and water heating in the United States and a dominant source of heating energy in colder regions, according to the U.S. Energy Information Administration [1]. Natural gas consists mainly of methane and is considered the cleanest fuel fossil energy source, due to lower carbon dioxide per unit of energy released. To further reduce the environmental impact of natural gas, North American natural gas utilities are envisioning the introduction of renewable natural gas (RNG) into the North American natural gas system. RNG, also referred to as biomethane, is considered a carbon-neutral energy source since it captures methane emitted from the decaying organic waste that would otherwise escape into the atmosphere. RNG by most traditional definitions is a methane-rich gas obtained via upgrade or purification of biogas, i.e., gas derived from biomass [2].

In addition to RNG, the gas industry is further considering the addition of green hydrogen (H_2), produced from renewable sources, to natural gas to generate hydrogen-enriched natural gases (HENG), or blends of natural gas and hydrogen. Natural gas/hydrogen blending is considered by its proponents as a means of reducing carbon-containing air emissions, principally carbon dioxide (CO_2), as hydrogen, during combustion in oxygen, produces water vapor. Although HENG as a term implies that the two gases are mixed in any proportion, the mixture containing 10 to 20% hydrogen by volume represents the most promising near-term option for reducing the overall "carbon footprint" from the burning of natural gas [3].

Implicit in natural gas/hydrogen blending is the trade-off between reducing the carbon footprint and the interchangeability of these gas blends with natural gas. Potential issues of pipeline and end-use system and equipment durability associated with hydrogen introduction in the natural gas, including HENG, embrace the potential for corrosive effects of molecular hydrogen. As the amount of hydrogen determines both physical and chemical properties of the HENG, the safety and suitability of different mixture compositions in residential applications are becoming a focus of interest. Contemporary studies of HENG compatibility with traditional natural gas systems are, therefore, receiving renewed examination since first studied on a major scale in the "hydrogen economy" of the 1970s.

The references to hydrogen levels that are safe for North American appliances are still scarce, but it was concluded that "hydrogen concentrations up to 28% may safely be used with properly serviced existing domestic appliances" [4], although this conclusion is tentative and needs to be confirmed through continuing research and analysis. North American natural gas utilities have articulated future targets for blending are up to 15% of hydrogen. Specific commitments and timetables for blending have identified 5% blending as the near-term target. In Canada, for example, the energy delivery company Enbridge is already blending 2% of hydrogen into the natural gas delivery system to the City of Markham.

An Alberta energy company, ATCO, has announced its plans to build Alberta's first natural gas/hydrogen blending project, injecting up to 5% of hydrogen into Fort Saskatchewan's natural gas distribution network. Even more advanced efforts are underway in Europe, East Asia, and Oceania.

Performance and operational safety of natural gas residential appliances are tested according to the North American CSA/ANSI Z21 series of Standards. Performance testing to CSA/ANSI Z21 Standards requirements of appliances operated on HENG has been largely unstudied. The objective of this research was to conduct an exploratory study on performance of gas appliances fuelled by mixtures of natural gases containing up to 15% hydrogen. It is anticipated that this exploratory testing will identify future standards development activities and appliance testing needs and policy development towards better-informed decision-making.

1.1 Background and Literature Review

1.1.1 Interchangeability of Gases

Design and performance of residential appliances are dictated by combustion energy output (heating value) of fuel gases, currently including conventional natural gases and variants to conventional natural gases. Using gases that are not compatible with appliances' design can cause many issues, such as incomplete combustion and, therefore, increased level of emissions of carbon monoxide, decreased efficiency and lifetime of the appliances. For example, in the UK, the incompatibility between natural gas and appliances designed for use with a gas manufactured from coal and oil (town gas) required a costly £500-million conversion of all UK gas appliances upon its mains-distributed fuel change in 1966 [5].

The compatibility between the gases, i.e., their interchangeability in appliance applications, is nowadays most commonly determined by an empirical value called the Wobbe index. Two gases that produce the same energy and density when applied at the same supply pressure have a similar Wobbe index (I_W), which is calculated as a ratio of gas higher heating value (HHV) and square root of gas specific gravity *(sp)* of the fuel gas to air under standard conditions.

$$I_w = \frac{HHV}{\sqrt{sp}}$$

Minimum and maximum Wobbe index requirements, along with HHV requirements, have been used as specifications for gases traded in the United States, as laid out in the Federal Energy Regulatory Commission's (FERC) Policy Statement on Natural Gas Interchangeability [6]. FERC further defines interchangeability as "The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing air pollutant emissions". Trade with Canada under TransCanada General Terms and Conditions of the Transportation Tariff also specifies minimum and maximum Wobbe values as natural gas interchangeability indices [7].

When compared to natural gas, hydrogen has lower specific gravity and lower heating value by volume that overall results in a lower HENG Wobbe index than that of natural gas. Although the Wobbe index is determined to be the best single-parameter measure of gas interchangeability, a simple comparison of the Wobbe index of HENG to the natural gas is not a reliable predictor for HENG uses in residential appliances for three reasons: (i) the Wobbe index of HENG non-linearly changes with the hydrogen content [8]; (ii) the Wobbe index cannot completely predict gas interchangeability as it does not account for all combustion phenomena [9]; and (iii) the Wobbe index and HHV generally refer to burner performance but not appliance operation per se. The most comprehensive and accurate information on compatibility of a gas with a given design of appliances is therefore obtained by testing the performance parameters of the appliances in laboratory settings through standard testing procedures. In North America, testing of space heating and water heating appliances subject to this research is performed through methods outlined in the binational CSA/ANSI Z21 series of Standards.

1.1.2 Heating Appliances Combustion Process

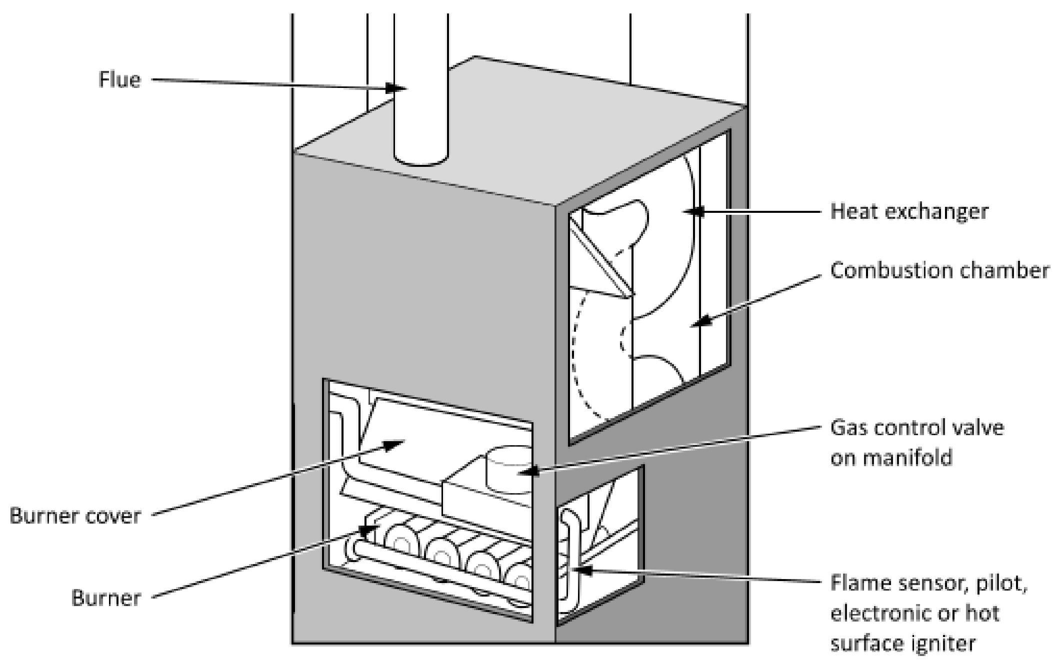
To understand the effects HENG can have on performance of heating appliances, it is important to understand the combustion process and components of the appliances. Fuel gases (usually natural gas or liquid propane) are supplied to the appliance at a given pressure that is controlled by an external delivery line pressure regulator followed by an internal appliance "step down" pressure regulator. The pressures of natural gas in the line are typically at least 1 in wc (inches of water column) higher than the manifold (i.e., operating) pressures of the appliance burner, although in many distribution systems and for many appliances, this pressure differential must be higher to ensure proper functioning of the appliance regulation.

The reduction from line to manifold pressure is set and maintained by a manifold serving the burners. In some appliances, manifold pressure is adjustable to compensate for local supplier gas compositional characteristics. In other and more modern appliances, manifold pressure is not generally adjustable and other means are used to control gas flow to appliance burners. A manifold is, simply speaking, a gas distribution apparatus serving the appliance burners that consists of pipes, connectors, valves, and various instruments for measuring and controlling the gas flow, as shown in an example of warm air residential furnace in Figure 1. Manifold pressure adjustment may be used to adjust fuel gas supply, as the appliances are designed to operate at specific heat input rates, i.e., amount of heat transferred to the burner over a period of time.

When the system calls for heat, the control valve upstream of the manifold opens and the ignition device ignites the gas inside the burner, which is a set of tubes through which gas is directed and burned. Different appliances and designs within appliance categories have different ignition devices, but they can be broadly divided into standing pilots (continuously burning flames) and electronic ignition systems. The ignition and gas combustion is monitored by a flame sensor that acts as a safeguard and shuts off the incoming gas if a flame is not detected.

Manifolds, burners, and other described devices directly associated with the combustion process are located inside a combustion chamber surrounded by a heat exchanger in the case of appliances that transfer heat energy from combustion to a circulating medium. The flames heat up a heat exchanger that then transfers energy to the heating medium – air in the

Figure 1: Main components of a gas heating appliance, depicted in a furnace example



case of furnaces and water in the case of boilers and water heaters. Unvented appliances, such as unvented space heaters examined in this study, do not have heat exchangers and instead transfer heat energy directly to the occupancy air. In the case of vented appliances (furnaces, boilers, and water heaters) gases formed during the combustion in the chamber are exhausted out through an appliance passageway or flue. The appliances' flue, which is an external but integral part of appliances in most cases, is connected to a venting system. The distinction of appliance "flues" from "vents" or "venting systems" is important, the latter being a structural component of the building.

The composition of the exhaust gases is determined by the gas burning process. In the case of complete combustion, which happens when the air and gas mix in optimal (stoichiometric) ratio or in excess air amounts, natural gas is ultimately converted to carbon dioxide and water, yielding blue-coloured flame and highest heat output. In cases of incomplete combustion, the efficiencies of the appliances are lower and carbon monoxide, water, and carbon are present in the flue emissions. Incomplete combustion can also result in buildup of soot and is characterized by an orange flame.

1.1.3 Appliance Design and Categories

Appliances examined in this study include four residential service gas-fired product categories, among which there are several classes[1]:

- Residential warm air furnaces (four units tested)
- Residential hot water boilers (four units tested)
- Residential service storage water heaters (two units tested)
- Residential unvented space heaters (two units tested)

Most homes in North America are heated with gas central heating systems, i.e., furnaces and boilers. While furnaces heat air directly and distribute hot air via ducts, boilers heat water and produce either steam or hot water, that further transfer heat to air mainly via radiators and radiant floor systems. Hot water boilers are closed loop systems, returning water to the boiler for reheating once space heating circulation is performed. Water heaters, on other hand, heat water for domestic purposes (cooking, cleaning, and bathing) that can be used as a potable (safe-for-drinking) warm water.

Among furnaces, boilers, and some water heaters, there are several distinct designs for **combustion control**, including *single-stage, two-stage and modulating* input rate controllers. A single-stage appliance operates at only one input rate and provides one heat output. Two-stage and modulating input rate heating systems are designed towards higher efficiencies of natural gas use. The two-stage heating means the heating system can operate at two heat output levels to satisfy two ranges of heat demand. On cold winter days, they provide high heat output by consuming more gas, i.e., they operate at a high input rate. During milder days, which account for 80% of a heating season, they operate at a lower input rate. The gas input to the appliance and the circulating air and water distribution speed are adjusted to a lower rate by furnace fans and boiler water pump control systems, respectively, thus improving not only gas but electrical energy efficiency as well.

Residential modulating appliances differ from two-stage appliances by providing continuous adjustment of gas input and fan/water pump speeds across the operating spectrum. Typically, modulating appliances provide approximately 70 discrete combinations of gas inputs adjusted for approximately 1°F difference in heat demand.

Most modulating appliances use a two-heat **exchanger configuration** to transfer heat to circulating heating medium. The first heat exchanger transfers heat in a manner comparable to the single- and two-stage appliance design discussed above. Cooled combustion gases approaching the dew point, i.e., temperature of condensation, are then passed through the second exchanger in which they are condensed and the heat of condensation collected is used for heating. This additional heat capture is formally distinguished as latent heat of condensation. Appliances of this type are referred to as *condensing combustion appliances.*

[1] Product classes are defined by the U.S. Department of Energy to delineate residential gas-fired products according to similarity of energy services provided. Within each product class, technology and designs can vary significantly in providing their common energy service functions.

"Overall, appliance designs that employ the condensing approach boost the overall operating efficiency of the appliance operating on natural gas by 10 to 18%, depending upon the design and rated efficiency performance."

Theoretically, latent heat of methane combustion increases recoverable heat by approximately 12% over one heat exchange. Overall, appliance designs that employ the condensing approach boost the overall operating efficiency of the appliance operating on natural gas by 10 to 18%, depending upon the design and rated efficiency performance.

Condensing appliances must dispose condensed water to a safe location outside of the furnace, typically a floor drain or outdoor condensate line. The acidity of condensed water in non-condensing appliances, measured as a pH value, should be relatively neutral (pH ~7) to avoid issues of corrosion and deposition of solids dissolved in the condensate. Non-condensing appliances are not designed for managing high acidity condensate (for example, less than pH 5) as water vapor is vented with other combustion products through the flue and house venting system, carrying with it gases and solids that can alter pH when in condensed form. In contrast, condensing appliances are designed to withstand acidities in the pH range of 2 to 5 without incurring internal corrosion damage. Condensate disposal to floor drains and other external plumbing used for condensate removal must be, therefore, able to withstand these corrosive environments.

Besides the differences in combustion control and heat exchanger configuration, venting appliances differ in **venting systems**. Classic systems rely on *natural draft* to vent combustion products outside. Newer appliances use fans in so-called *power vented draft* systems that either push (forced draft systems) or pull (induced draft systems) air out of the occupancy during operation of the appliance. The two-stage heat recovery approach, in contrast to the one-stage, requires power venting to successfully vent the combustion products to the outdoors.

In natural draft appliances, some heat from the occupancy when the appliance is not operating is lost through the venting system. This issue is overcome with an automatic device, a vent damper, that shuts off the flue pipe when the burner is not running and is most commonly used in some boiler designs. Use of vent dampers improves efficiency on the order of 1 to 3%. Besides the *vent damper,* combustion gases can be vented to the outdoors without the addition of room air for dilution via *direct venting*. In direct venting appliances, outside air is used both as a combustion supply for stoichiometric combustion and dilution air, which is not used in combustion but assists in venting of combustion gases. This is typically done using an annular, "pipe-within-a pipe" venting system design where an inner pipe vents combustion products, while a surrounding outer pipe brings in outside air for combustion. This direct vent design and combustion air supply typically boosts overall boiler efficiency by over 10% in rated performance.

As already stated, unvented gas space heaters combust gas and release heat and combustion products directly to the occupied space. These appliances do not use heat exchangers or flue systems to separate combustion from occupancy air.

Combustion gases are exchanged with occupancy air via convection or in some designs with the use of a small blower to promote heated air distribution. Unvented space heaters may be either "blue flame" designs or radiant burner designs (Figure 2). "Blue flame" unvented space heaters use a conventional burner tube with ports that support a conventional diffusion flame similar to a cook top burner, but usually configured as a tube to enhance heat transfer to the room air. Radiant space heaters, often referred to as infrared space heaters, generate infrared radiation through tile or metal matrix structures, thus transferring heat to the room air both by convection and radiation.

In some North American jurisdictions, most notably in Canada and in some states of the US, unvented heaters are not permitted because of concerns of combustion products accumulation in occupancies and potential health, safety, and building durability issues associated with CO, NO_2, and water vapor accumulation. In response to these concerns, the CSA/ANSI Z21.11.2 Standard, *Gas-fired Room Heaters, Volume II, Unvented Room Heaters,* covering unvented space heaters, requires demonstration of NO_2 air-free emission rates below 20 ppm, CO air-free emission rates below 200 ppm, and installation of an oxygen depletion sensor (ODS), which controls the main gas value and shuts down the appliance when oxygen levels drop below 18%. The oxygen level drop is highly correlated to hazardous CO level build up so that it serves as a proxy for avoiding CO accumulation that would present occupant safety issues.

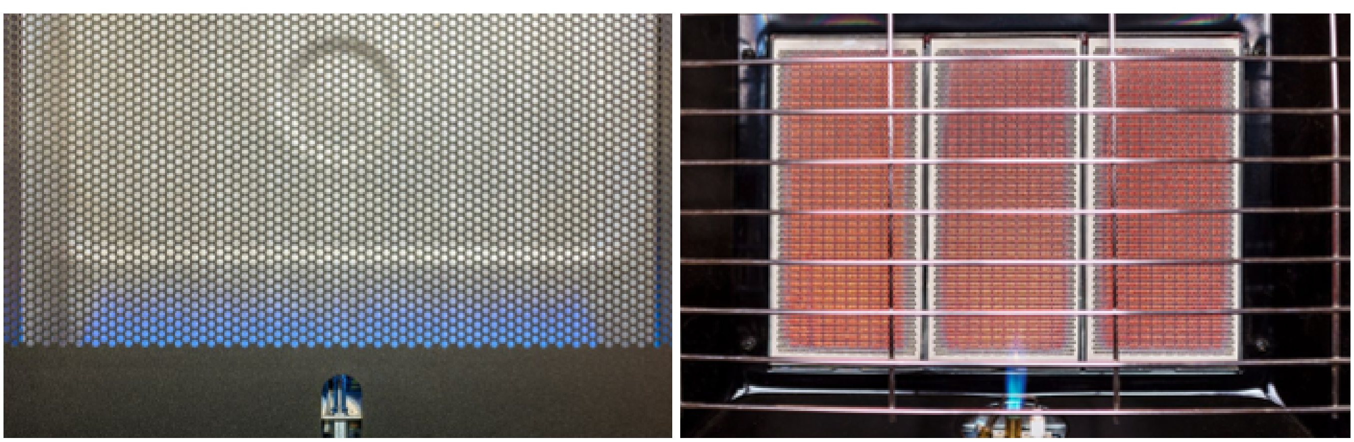
Besides being unvented, the space heaters differ from the vented appliances by not requiring electrical supply, except in designs that utilize a blower for air circulation. Likewise, many designs of storage water heaters operate without electrical supply, although higher efficiency units use electric power for power venting and various controls. Furnaces and boilers, on the other hand, all require an electrical supply.

1.1.4 Performance Parameter (Tests) Indicators of Interchangeability

Performance of residential North American gas-fuelled space and water heating appliances and their certification is performed according to the binational CSA/ANSI Z21 series of Standards [10]–[13].

Major performance parameters tested across the appliance categories are similar. Before the actual performance testing is performed, the manifold pressures are adjusted within the manufacturer-set limits and the input rate (energy transferred to the burner) is measured to ensure that the appliance is operated as intended. Depending on the appliance type, testing is performed at higher and lower input rates as specified in the applicable standard. The subsequent performance test measurements at manufacturer-set input rate are performed under a steady-state operation,

Figure 2: Blue Flame Space Heater Flame Section (left) and Infrared Gas Ceramic Tile Space Heater Closeup (Right)



i.e., at constant temperatures, combustion conditions, and emissions. To test for interchangeability of gases, the following major tests need to be performed to ensure proper operations and safety.

1.1.4.1 Ignition

Initially, a successful ignition of the main appliance burner(s) per attempt is evaluated on a "pass/fail" basis under pressures and voltages within the range of operation limits. Any changes in ignition performance due to operation on HENG is of principal interest.

It has been shown that at low concentrations of hydrogen in air, the energy required to initiate combustion is similar to that of other fuels. However, at concentrations of 29% hydrogen-to-air volume ratio, the ignition energy is ten times lower than that required for natural gas [14]. In case of HENG uses in appliances, hydrogen ignition over a wide range of concentrations in air could cause inconsistent performance of appliance ignition systems, requiring the system to constantly reset and restart.

1.1.4.2 Burner Operating Characteristics (BOC)

For the appliances to operate at the design process flowrate, the burners need to provide the heat necessary to maintain heating medium temperature and meet flame and vaporization requirements to maximize heat exchange. The production of the heat depends on combustion of the air and gas mixture. Under complete combustion, the flame is substantially blue and stable and of a given geometry – without floating around the edges, drifting out or lifting off the burner, or burning back into burner ports. In the case of improper burner operation however, a set of undesired observations serve as indicators for failed operation:

- Flash back (or flashback) is the burning of gases back into the burner ports and within the manifold system, rather than inside the burner. In cases of an incompatible fuel use, it can be caused by an excess amount of air in the system, or too low input rate, affecting the burner stability, efficiency, and potentially safety associated with changes in appliance emissions characteristics.
- Flame lifting off the burner is the ignition of fuel gas and air mixtures above the appliance burner port(s) during operation. This phenomenon can affect stability and efficiency of the appliance and potentially safety associated with improper heat transfer and changes in appliance emissions characteristics. Flame lifting off the burner is usually caused by an excessive amount of air or too high input rate (overfiring), resulting in operations at too high temperatures, incomplete combustion, and reduced burner efficiency.
- Higher flow rates and lowered flow resistance of hydrogen may cause flame lifting and consequently, temperature distance from the heating surface may differ depending on hydrogen content (e.g., a pot being heated on the sides instead of on the bottom).
- Delayed ignition, similar to the flashback, represents the ignition of fuel/air gas mixture outside the burner and within the combustion chamber due to failure of immediate ignition of the burner as designed for the appliance, potentially affecting safety.
- Excess noise from combustion is usually due to an excessive flow of fuel gas, and air, or fuel gas and air mixtures.
- Overpressure upon ignition is the development of impulse pressure (explosion) outside of the burner, most commonly resulting from delayed ignition.

BOC behaviours are observed during combustion performance tests. They are not tested independently or quantitatively evaluated. The results are evaluated on a qualitative pass/fail basis.

1.1.4.3 Temperature Rise Test

Temperature rise measures a difference in the temperature of the heating medium before and after heating. It is assessed during the stabilization phase of appliance operation over a standard-prescribed test duration period. Temperature rises prior to achieving steady-state temperatures may alter combustion behaviour and emissions characteristics. It is expected that at a set pressure of applied gas, hydrogen could lower the temperature rise of appliances fuelled by HENG due to its lower heating value.

1.1.4.4 Combustion Tests

A complete combustion of gases is important not only for the performance of the appliances and efficient use of the fuel but also for safe operations, i.e., emissions of nitrogen and carbon monoxide formed during combustion that must remain at levels deemed safe for humans and the environment in the limits guided by regional regulations. The combustion tests are performed for concentrations of NO_x and CO_x in flue gases.

Nitrogen oxides (NO_x), which are atmospheric ozone creation precursors, are produced in appliances mainly by thermal reactions in high temperature flame zones near the burners [15]. The flame temperature of the HENG might be different in the presence of hydrogen fractions due to the higher flame temperature of hydrogen gas as compared to methane flame temperatures, possibly resulting in higher NO_x concentrations. NO_x concentrations for combustion analysis, that include all forms of nitrogen oxides, are reported and limited to a concentration of air-free NO_x (NO_x AF). Air-free concentration of any gas is a corrected value of a gas concentration to simulated air-free conditions in the combustion gases. The air-free concentration calculation is based on theoretical complete combustion that yields either zero oxygen or "ultimate CO_2" amounts, i.e., total conversion of carbon to CO_2. Adjusting combustion gas measurements to air-free measurements using either oxygen or CO_2 allows for consistent combustion performance measurements across appliances by removing the contribution of air not directly involved in the combustion process (i.e., excess air).

To perform the calculation based on oxygen-free calculations, the oxygen amount in a combustion gas is measured along with the emission gas of interest and a ratio of the measured oxygen concentration to theoretical 20.9% maximum concentration of oxygen in natural gas is used as a correction factor using the following calculation:

$$NO_x\ AF(ppm) = \frac{20.9\%}{20.9 - O_2(\%)} \cdot NO_x(ppm)$$

where:

NO_x AF – calculated air-free NO_x concentration (ppm),

O_2 – measured percentage of oxygen in combustion gas, and

NO_x – measured concentration of NO_x in combustion gas (ppm).

If the calculation is based on CO_2 measurements, then the following equation is used:

$$NO_x\ AF(ppm) = \frac{12.2\%}{CO_2(\%)} \cdot NO_x(ppm)$$

where 12.2% represents the maximum concentration of CO_2 in natural gas (ultimate CO_2) and CO_2 is a measured concentration of CO_2 in flue gases.

NO_x AF maximum thresholds are set under jurisdictional requirements, most notably limits set by the California South Coast Air Quality Management District (SCAQMD) in the US [16]. Although most gas appliance standards used in this study do not set emission thresholds for NO_x AF, the CSA/ANSI Z21.11.2 Standard covering unvented space heaters limits NO_2 AF concentrations to 20 ppm, since NO_2 is associated with the health effects of building occupants when breathing concentrations exceeding health-based guidelines and standards.

Carbon oxide (CO_x) concentrations, are also important parameters of complete and incomplete combustion process. CO_2, a product of complete combustion, is usually reported as measured in samples for the purpose of calculating air-free concentrations of other gases (NO_x, NO_2, and CO), while CO is reported as air-free (CO AF) calculated value, using similar equations as those shown above. The limited amount of CO AF resulting from combustion of natural gas is limited to 400 ppm in most CSA/ANSI Z21 series of Standards.

The addition of hydrogen to HENG is expected to ultimately lower CO_x emissions since carbon levels are reduced in the fuel gas used in combustion. However, considering the lower HHV of hydrogen, it is plausible that higher amounts of HENG are likely to be needed to achieve the equivalent energy output obtained with the lower amounts of natural gas. This could in turn mean that overall carbon reduction proportional to the hydrogen added may not be achieved.

"The addition of hydrogen to HENG is expected to ultimately lower CO_x emissions since carbon levels are reduced in the fuel gas used in combustion."

1.1.4.5 Flue Loss

Flue loss is heat contained in flue gases above room temperature that leaves the appliance. It is used to approximate combustion and heat transfer efficiency of the appliance. Regulatory-prescribed efficiency testing is used to demonstrate compliance with minimum efficiency requirements, account for factors such as seasonal usage patterns, consumer-specific usage patterns, and other variables that approximate annual efficiency performance. However, as these testing methods and metrics differ across appliances, flue loss measurements provide a more consistent means of determining efficiency for comparison purposes.

1.1.4.6 Condensing Appliances Condensate Measurements

Condensing appliances are additionally assessed for dew point temperatures and acidity. Dew point represents the temperature at which moisture in combustion gases condense into liquid water. Most condensate from natural gas appliances will have a pH of between 2 and 4, according to the chemical composition of the used fuel. Condensate acidity is affected by the generation of carbon, nitrogen, and other elemental solutes, which originate from combustion products, dilution air, and trace sources.

2 Methodology

2.1 Appliances and Verification Testing

Appliances used in this study were donated by the Air-Conditioning, Heating and Refridgeration Institute (AHRI) and previously tested for other purposes.

The study included a variety of appliance categories and classes as listed in Table 1 and detailed more fully in the tables in Appendix A.

Before the actual performance test for different gas mixtures was performed, the appliances were tested to confirm satisfactory performance using service "line gas", i.e., natural gas provided by an energy company. The testing verified the burner input rate based on gas consumption at input rating settings and, CO_2 and CO AF emissions. In the case of furnaces, tests were performed under normal and high external (in ducts) static pressures and additionally included a temperature rise test. Verification testing also included visual assessment of ignition and BOC that were performed on appliances operating under reduced, normal, and increased inlet test pressures (3.5, 7.0, and 10.5 in wc) with the supply voltage adjusted to 85% and 110%, as well as at appliance rating plate voltage (102, 120, and 132 V). Unvented space heaters were tested only under three line-pressures, as their operation does not require electricity input.

Issues raised during the verification tests included:

- FURN1 could not be ignited at 102 V current – the tests requiring this voltage were therefore performed at 105 V;
- WH2 design prohibited visual observation of the burner port, therefore the ignition test was assessed via successful ignition and the absence of noise during ignition and shutoff; and

Table 1: Classes and Descriptions of Appliance Studied for Use of Methane/Hydrogen Blends

Appliance Category	Appliance Class	Designation
Residential furnaces	2-stage, non-condensing, induced draft	FURN1
	2-stage, non-condensing, induced draft	FURN2
	2-stage, condensing, induced draft	FURN3
	Modulating, condensing, forced draft	FURN4
Residential boilers	1-stage, non-condensing, draft hood	BLR1
	1-stage, non-condensing, vent damper	BLR2
	Modulating, condensing, direct vent	BLR3
	Modulating, condensing, direct vent	BLR4
Residential water heaters	1-stage, non-condensing, induced draft venting	WH1
	1-stage, non-condensing, draft hood	WH2
Residential unvented space heaters	Blue flame	SP1
	Infrared	SP2

- SP1 showed limited operations at lower manifold pressures. Therefore, ignition and BOC tests specific for the space heater of this design, specified in the CSA/ANSI Z21.11.2 Standard that requires testing under 50% manifold pressures and 87% minimum input rate, could not be performed.

Despite these observations, the appliances were used within their limits and these limitations were noted under applicable results as the intent of this study was to compare performance of appliances fuelled by different gas mixtures under the same conditions. As the appliances were previously used for testing at other labs, a test failure doesn't necessarily mean that a new unit from the manufacturer would also fail.

2.2 Materials

Pure methane and hydrogen were purchased from Airgas. Pure methane gas was used in the performance tests as a baseline for performance and as a proxy for natural gas. Pure methane was used in all gas blend tests to avoid artifacts that might be introduced by irregularities in composition of line natural gas over the course of the testing. Table 2 includes properties of pure methane and hydrogen/methane blended gases calculated using an unpublished American Gas Association (AGA) calculation procedure adopted by the AGA Gas Interchangeability Program [17]. Table 3 includes actual (measured) concentrations of methane and hydrogen gas in the blends used in this study, as provided by Airgas.

2.3 Testing

The appliances were tested for input rate, ignition and burner operating characteristics, combustion products properties, and gas leakage, using three gas mixtures (pure methane, 5% hydrogen/methane blend, and 15% hydrogen/methane blend mixtures) per applicable CSA/ANSI Z21 series Standards. Furnace testing also included the assessment of temperature rise and tube surface temperature measurements. A gas supply manifold, designed and manufactured for the purpose of this test, allowed for rapid changes in gases introduced to the appliance during the various tests. Adjustments in appliance setting such as manifold pressure and ignition voltage, were carried out manually. The manifold was purged every time before a new gas mixture was used.

Combustion products testing included CO_2 measurements, CO AF and NO_x AF calculations (NO_2 AF in case of unvented space heaters) and for vented appliances also encompassed flue temperature measurements and flue loss and dew point calculations. Acidity of the condensate was assessed through pH values for appliances classified

Table 2: Properties of Test Gases Calculated Using an Unpublished American Gas Association Calculation Procedure

Gas Property	Pure CH_4	5% H_2 / 95% CH_4	15% H_2 / 85% CH_4
Higher heating value (HHV), dry, standard conditions (Btu/ft^3)	1012	977.6	908.9
Specific gravity relative to air, standard conditions (dimensionless)	0.5539	0.5296	0.4812
Wobbe number (dimensionless)	1359.8	1343.3	1310.2
Air required for stoichiometric combustion per cubic foot of gas (ft^3)	9.53	9.17	8.46
Ultimate CO_2 produced from complete combustion (ft^3)	11.73	11.59	11.28

Table 3: Actual Concentration of Mixed Gas Components Used in the Study as Reported by Airgas

Nominal Mixture Composition	5% H_2 / 95% CH_4		15% H_2 / 85% CH_4	
Gas component	H_2	CH_4	H_2	CH_4
Minimum	5.148	94.776	14.90	84.88
Maximum	5.224	94.875	15.12	85.10
Average	5.188	94.816	15.00	85.00

as condensing appliances. The measurements were performed once, unless there was a need for repetition caused by erroneous testing, due to limitations of testing resources and the need to cover all appliance categories and classes with the various performance tests relevant to the standards.

In addition, heat exchanger tube temperature profiles of one furnace were created for all gases, and surface temperatures of unvented space heaters' IR burner and metal guard were measured.

The tests were performed according to applicable tests of the CSA/ANSI Z21 series Standards and briefly described as follows:

Manifold pressure was measured by in-line pressure meter or U-tube manometer.

Input rate was measured by the Elster American Meter Company DTM-200 flowmeter, after 15 minutes of operation and upon reaching a steady-state input rate in boilers and water heaters, as specified in applicable CSA/ANSI Z21 series Standards.

Ignition and BOC assessment was performed by visualization of ignition success, flame extinguishment, flame geometry, and excessive noise, at minimum and maximum input rates and at cold and high temperature operations, according to CSA/ANSI Z21 series Standards. Space heater ignition and BOC behaviours were also evaluated at 87% of minimal input rate and 123% of manufacturers' declared input rate, as per requirements of the CSA/ANSI Z21.11.2 Standard.

Combustion products testing:

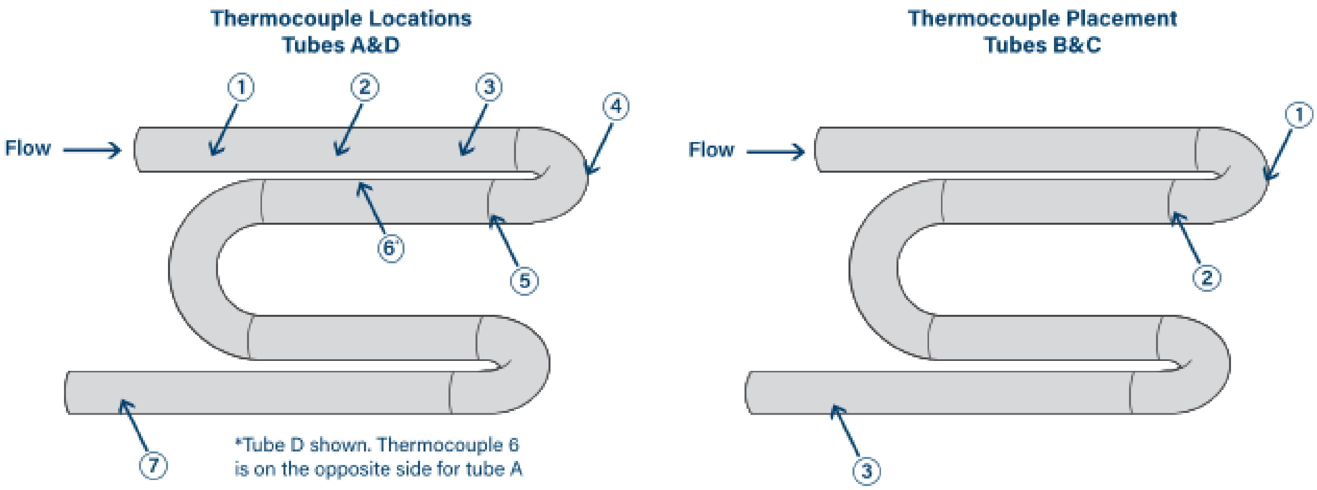
Concentrations of CO_2 and CO were measured by the Siemens Ultramat 23 gas analyzer following procedures of CSA/ANSI Z21 series Standards.

Concentrations of NO_x and NO_2 (for space heaters only) were measured by the Thermo Scientific™ 42i-LS NO-NO_2-NO_x Analyzer, on an air-free basis. Space heater NO_2 testing was performed according to the CSA/ANSI Z21.11.2 Standard. The instrument was calibrated according to the SCAQMD protocol [16].

Dew point was computed according to Brokaw [18].

Flue loss was determined according to equations given in Annex I of the ANSI Z21.47/CSA 2.3 Standard. The calculations were based on flue temperatures measured by Fluke 52 connected to Cleveland Electric Labs ITW-J-24-2-304-0-C or Omega PR-J-SLE-1000 thermocouples.

Figure 3: Placement of Thermocouples on Heat Exchange Tubes of the Furnace Selected for Examination (FURN1)



Condensate pH values were assessed for condensing type furnaces and boilers. The condensate was collected during flue loss testing and the pH measured using the Hanna Instruments HI98103 pH meter.

Leakage testing:

Assessment of leakage, which is not a part of the CSA/ANSI Z21 series Standards testing, involved pressurizing manifold gas lines from one of each of the four appliance categories to 10.5 in wc (0.4 psi) test gas and measuring pressure decay over time. The gas lines were completely closed using orifice blanks and filled with gas, leaving no air in the system. Every 30 minutes over a two-hour period, line pressure was recorded and leaks in the joints examined using both a gas sniffer and soap and water test. The gas sniffer, Inficon GAS-Mate®, had a sensitivity of 5 ppm for both CH_4 and H_2.

In addition to the manifold gas line, leak testing was also performed on piping connected to the appliances. Four piping materials were tested: steel pipe with threaded joints sealed with Rectorseal Tplus2TM pipe thread sealant, press connect copper, 45-degree flare connect copper, and corrugated stainless-steel tubing (CSST) with mechanical joints. Each piping assembly included a tee connection with 1 ft. piping terminated with a cap and 4 ft. piping terminated with a manual valve. The purpose of the manual valve is to purge the assembly of previous test gas when adding the next test gas.

Initially, quality of connections was verified using pressurized air at 20 psi. The verification included pressure loss monitoring at the 5-minute period and subsequent bubble appearance upon immersion in water. Upon satisfactory connection confirmation, three test gases at the pressures of 5 psi and 20 psi were examined for leakage under the same tests – pressure loss and bubbles visualization.

Temperature rise in furnaces was assessed as a difference between the temperatures of air entering the furnace and heated air in the furnaces ducts. The temperatures were measured by Fluke 52 using Omega PR-J-SLE-1000 thermocouples placed according to ANSI Z21.47/CSA 2.3 requirements based on furnaces properties.

Surface temperatures of the heat exchanger tubes of one two-stage, non-condensing furnace (FURN1) were measured using Cleveland Electric Labs ITW-J-24-2-304-0-C thermocouples connected to IOtech Personal Daq/56 USB data acquisition system. Position of the thermocouples on the furnace tubes is shown in Figure 3. Space heater metal guard temperatures were measured by Fluke 52 II and J-type thermocouples. Infrared tile temperatures, also recorded at multiple locations, were measured using Omegascope® OS523-3 infrared thermocouples assuming emissivity of 0.8 at normal manifold pressure.

Influence of hydrogen gas addition to methane on the performance of appliances was determined via examination of observable trends in measured values with hydrogen content increase. No statistical analysis was performed due to an insufficient number of replicates. Only patterns of consistent change due to hydrogen gas increase are reported here.

3 Results and Discussion

3.1 Residential Furnaces

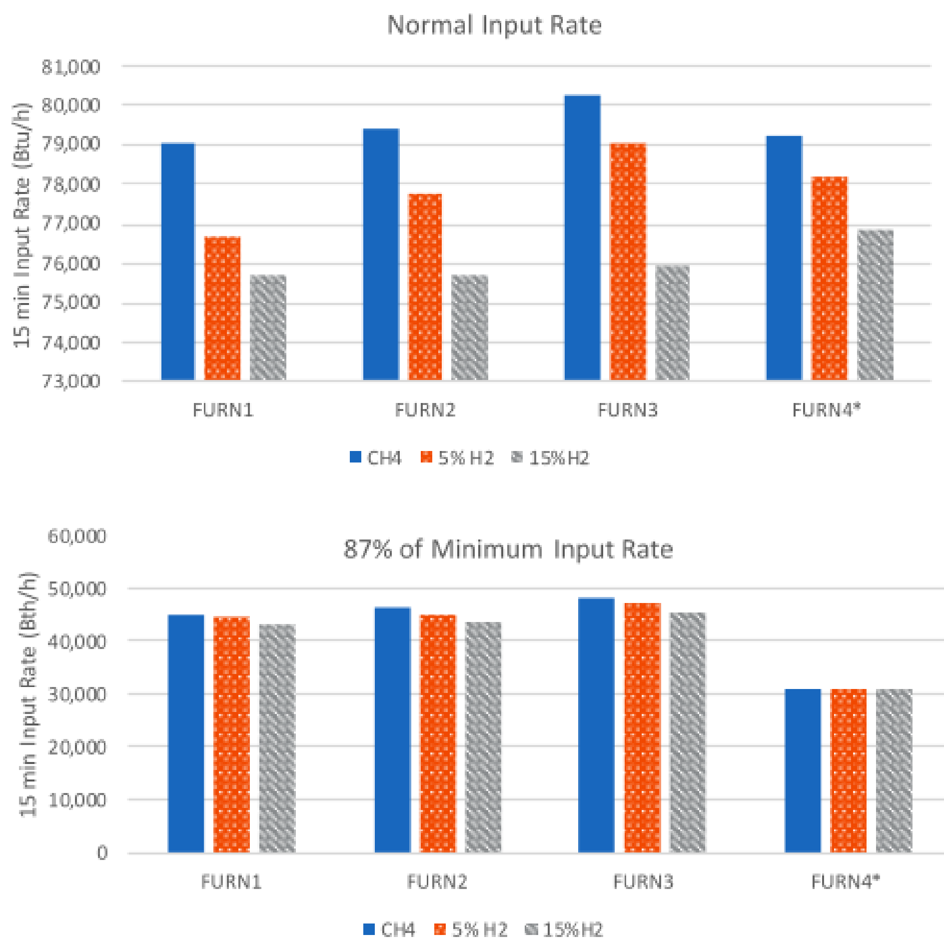
All furnaces passed ignition and BOC performance tests, regardless of the fuel used. Detailed results of performed tests are shown in Appendix B.

Consistent trends of hydrogen content increase were observed on the 15-minute input rate, CO_2 measured amounts, and the heat exchanger tube temperatures.

The most conspicuous effect of hydrogen content increase in gas mixtures on all furnaces was observed on the 15-minute input rate measurements for furnaces operated both at manufacturer-prescribed normal and 87% of minimum input rate at normal external static pressure, as shown in Figure 4. The only exception to this observation was a uniform 15-minute input rate of condensing furnaces operated under 87% minimum input rate. At equal manifold pressures, 5% gas blend-fired furnaces showed approximately 2% and 1.3% lower input rate for normal and 87% minimum input rate, respectively, when compared to the inputs of furnaces fuelled by methane. An additional drop in input rate was observed with the use of 15% gas-blend, displaying an overall decrease of approximately 4% from methane-fuelled furnaces.

Figure 4: Influence of Hydrogen Content on Input Rate of Furnaces Measured at Normal Input Rate (Top) and 87% of Minimum Input Rate (Bottom) at Normal External Static Pressures

Note that manifold pressures were set at normal and 87% minimum input rates for natural gas (control). The input rates of the test gases were then measured at these manifold pressures.



Similarly, at equal manifold pressures, changing gas from pure methane to a 5% hydrogen/methane blend lowered CO_2 content of combustion gases by 3 to 4% and 15% hydrogen further decreased CO_2 content by 10%. There was no apparent difference in NO_x AF and CO AF measured concentrations among the gas blends, recorded in the range of 77–87 ppm and 10–29 ppm, respectively. No consistent change with increase of hydrogen content was seen in these combustion gas levels. Dew point appeared also to be unaffected by hydrogen content in gas mixtures in all furnaces, while the flue loss did not exhibit a consistent change pattern. Differences in temperature rise were also inconsistent with the hydrogen amount increase.

Condensate pH of condensing furnaces was in the range of 3.7–3.8 for all measurements. No leakage of any gas was detected.

At constant manifold pressures, the lowest heat exchanger tube temperatures overall were measured in furnaces fuelled by 15% hydrogen/methane blends and the highest with the use of methane, with a few exceptions at the points closest to the gas entries (A1/D1 and A2/D2, see Figure 3), as shown in Table 4. On average, temperature drop roughly doubled with an increase of hydrogen from 5 to 15% (see average values in Table 4). Measurement of the temperatures at the constant input rates were suggesting the opposite effect, i.e., highest temperatures in the case of 15% hydrogen and lowest in the case of methane, although the trend was not as clear as in the case of constant manifold pressure.

3.2 Residential Boilers

All boilers exhibited similar ignition and BOC performance regardless of gas, except the one equipped with a draft hood, when fuelled by 15% hydrogen at inlet test pressure of 3.5 in wc of pressure. This testing condition frequently caused either continuous ignition spark after the flame was lit or loss of flames.

Boilers operated at the same manifold pressure, similar to furnaces, showed a consistent decrease in 15-minute and steady-state input rate with higher amounts of hydrogen. The same was observed for CO_2 emissions. See Appendix B for more detail. The introduction of 5% hydrogen caused a decrease in input rate at an average of 1.3% and 15% hydrogen content further decreased input rate to 3.7 to 3.8% for both 15-minute and steady-state input rates. CO_2 concentration in flue products decreased 5% and 10% with 5% and 15% hydrogen content, respectively, as was the case for furnaces. CO AF and NO_x AF in condensing boilers also showed a decline with increased hydrogen content (Figure 5), but non-condensing boilers deviated from this trend. The decrease in condensing boiler CO AF emissions was on average 18% and 41% and NO_x AF emissions were 15% and 30%, with the increase to 5% and 15% hydrogen, respectively. The overall measured values of CO AF were in the range of 9–150 ppm and 21–140 ppm for NO_x AF for condensing and non-condensing boilers. Like furnaces, differences in dew point temperatures were comparable. Acidity of condensate was similar across all four units and for all test gases, with the pH value in the range of 2.4–3.0. No leakage of any gas was detected.

3.3 Residential Storage Water Heaters

Water heaters also passed ignition and BOC testing regardless of the gases used and similar to furnaces and boilers, showed a decrease in input rates and CO_2 emissions with an increase in hydrogen amounts. At 5% hydrogen, the 15-minute and steady-state input rate decreased approximately 1 to 1.8%, and at 15% hydrogen, the 15-minute input rate decreased on average 4% and the steady-state input rate decreased approximately 4.3% when compared to their respective inputs when methane was used (see Appendix B). Also in agreement with furnaces and boilers, CO_2 emissions decreased 5% and 11% with the use of 5% and 15% hydrogen/methane blends, respectively. CO AF was in the range of 2–21 ppm and 11–108 ppm for NO_x AF, without any obvious effect of hydrogen amount increases. The same independence was observed for other measured flue properties. No leakage of any gas was detected.

3.4 Residential Unvented Space Heaters

Change of test gases did not affect ignition performance and BOC performance was similar for all test gases on both space heaters. However, unvented space heaters exhibited several nonconformities when using methane/hydrogen blend with 15% hydrogen content:

- The blue flame space heater using 15% hydrogen consistently extinguished in less than one hour of continuous operation due to instability of the igniter flame.

- At 123% of high input rate and 15% hydrogen, flame tips of the blue flame unit appeared to reach the top of the porcelainized area, which was not the case when tested with pure methane or 5% hydrogen/methane blend.
- The 15% gas mixture extinguished the flame earlier than for the other test gases for the blue flame space heater when operating the gas valve for lower input.
- The emission test requiring the use of a hood introduced too much dilution air to permit reliable air-free calculations for determining the effect of hydrogen mixtures.

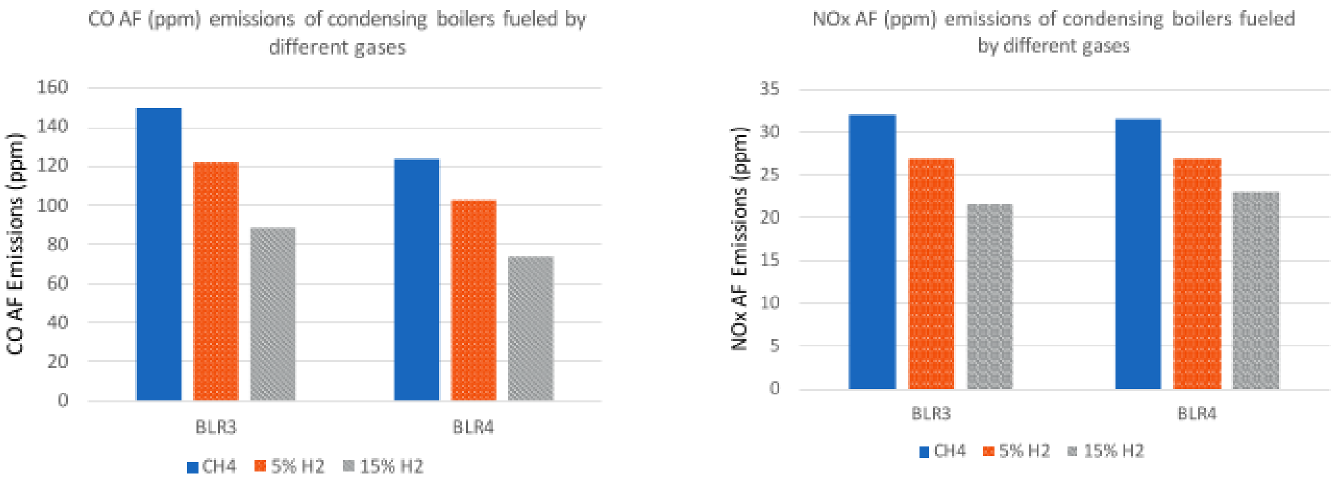
Despite these observations, unvented space heaters also showed a decrease in the 15-minute input rate with an increase in hydrogen gas when tested under the same manifold pressures, with decreases up to

Table 4: Average temperatures of four furnace heat exchange tubes taken along several points (tubes A and D temperatures measured at 7 locations; tubes B and C temperatures measured at 3 locations) as affected by gases at constant manifold pressure. The cells with the highest temperature among the three gases, measured at the same point, are shaded in dark gray and cells with the minimum temperature are shown in white

Test Gas	Input Rate (Btu/h)	Thermocouple Locations Temperature (°F)							
Tube A		A1	A2	A3	A4	A5	A6	A7	Average
CH_4	77,730	255	387	389	584	682	394	295	
5% H_2	75,840	260	388	385	571	668	387	292	
15% H_2	74,130	263	387	376	554	649	376	287	
Temp decrease using 5% H_2/methane blend				1.0%	2.2%	2.1%	1.8%	1.0%	1.6%
Temp decrease using 15% H_2/methane blend				3.3%	5.1%	4.8%	4.6%	2.7%	4.1%
Tube D		D1	D2	D3	D4	D5	D6	D7	Average
CH_4	77,730	192	421	461	528	689	476	304	
5% H_2	75,840	194	418	451	521	675	467	300	
15% H_2	74,130	201	413	440	514	660	453	293	
Temp decrease using 5% H_2/methane blend			0.7%	2.2%	1.3%	2.0%	1.9%	1.3%	1.7%
Temp decrease using 15% H_2/methane blend			1.9%	4.6%	2.7%	4.2%	4.8%	3.6%	4.0%

Test Gas	Input Rate (Btu/h)	Thermocouple Locations Temperature (°F)			
TUBE B		B1	B2	B3	Average
CH_4	77,730	580	755	277	
5% H_2	75,840	555	716	274	
15% H_2	74,130	534	683	269	
Temp decrease using 5% H_2/methane blend		4.3%	5.2%	1.1%	3.5%
Temp decrease using 15% H_2/methane blend		7.9%	9.5%	2.9%	6.8%
Tube C		C1	C2	C3	Average
CH_4	77,730	542	696	289	
5% H_2	75,840	519	663	287	
15% H_2	74,130	503	641	280	
Temp decrease using 5% H_2/methane blend		4.2%	4.7%	0.7%	3.2%
Temp decrease using 15% H_2/methane blend		7.2%	7.9%	3.1%	6.1%

Figure 5: Change in CO AF and NOx AF Emissions (ppm) of Condensing Boilers (BLR3 and BLR4) with Changes in Hydrogen Content



1.5% using 5% hydrogen/methane blend for blue flame heaters and 5% using 15% hydrogen content blend in infrared heaters. CO_2 emissions showed a decreasing trend with increased hydrogen amounts only in the infrared unit, with simultaneous increases in CO AF and NO_2 AF concentrations. The overall measured values of CO AF and NO_2 AF were in the range of 12–68 ppm and 9–12.5 ppm, respectively. No leakage of any gas was detected. Detailed results of performed tests are shown in Appendix B.

Temperatures measured at various positions of IR burner and metal guard surface temperatures also did not show any consistent difference between the gases.

3.5 Gas Leakage in Pipes

Similar to the absence of leakage in appliance manifolds, all of the piping assemblies passed pressure loss or bubble tests, regardless of the test gas and pressures used, or piping type. Therefore, the test results indicate that the addition of hydrogen up to 15% shouldn't introduce a leak concern in indoor piping.

4 Discussion and Other Considerations

The results generally demonstrated that the mixtures of methane and hydrogen up to 15% do not present operability challenges and no critical issues were identified for operating appliances tested using CSA/ANSI Z21 standard test protocols. In addition, CO and NO_x emissions of all appliances remained below acceptable levels. The physical properties of the gas blends, such as reduced gas density, did not appear to negatively affect appliance controls or leakage from connected supply tubing. One exception in appliance control operation might be inferred from the inability of one space heater to maintain stable pilot behaviour and presumably going into shutdown by the ODS as a result. This behaviour may represent issues for other pilot ignition and pilot-related safety devices, the latter including atmospheric burner storage water heaters and unvented space heaters, both of which use pilot stability in shutoff safety devices. In unvented space heaters, the safety function shuts off the main burner in response to oxygen depletion and correlated accumulation of CO.

The addition of hydrogen to the gas supply was expected to lower input rates due to a lower hydrogen heating value, but not affect the operation of the system. The results proved the expectations to be valid for all appliances. This measured reduction in input rate consequently led to lower heat output, as indicated by the decreased temperatures of heat exchange tubes when using higher hydrogen fractions. This would suggest that higher amounts of hydrogen-blended gas are required to provide equivalent heat of pure methane and by inference, natural gas. The results also consistently showed a decrease in CO_2 emission with

"The addition of hydrogen to the gas supply was expected to lower input rates due to a lower hydrogen heating value, but not affect the operation of the system. The results proved the expectations to be valid for all appliances."

with the increase of hydrogen content across the tested appliances. The observed hydrogen effects of a decreased input rate and postulated increased use of HENG on one hand, and the decreased CO_2 emissions on the other hand, naturally raise the question of the levels of CO_2 emissions decrease at equivalent rates of heat output.

In an attempt to provide some insight to this question, we further compared the percent decrease in released CO_2 to the percent decrease in temperatures of heat exchange tubes of the examined furnace. For the two-stage, non-condensing furnace (FURN1), the 5% hydrogen/methane gas blend yielded a 2.6% CO_2 decrease and 2.5% decrease in tube temperatures and the 15% hydrogen/methane blend showed a 9.9% decrease of CO_2 and overall 5.2% tube temperature decrease. These extremely simplified comparisons indicate that there are overall potential benefits in using higher hydrogen content gas blends in terms of CO_2 emissions versus heat output, but only a full-cycle analysis of hydrogen production and use as a supplement for natural gas, with a detailed examination of the heat output requirements, could give complete insight into the overall advantage of HENG applications.

The insignificant change in CO AF, despite decreased CO_2 emissions with the use of hydrogen/methane blends versus methane, was also expected, considering the differences in the ultimate CO_2 factor for these two gases. No pattern in NO_x emissions can further be explained by trace amounts of nitrogen in the test gases.

The steady flue loss and dew points across different gases in all appliances can also be explained by insignificant differences in the tested range of gas mixtures to show an effect.

In the residential furnaces tested, the effect on modulating condensing furnaces was expected to push operation modulation into higher input rates and fan speeds to compensate for reduced heating value of the gas mixture. As a practical response to these differences, manifold pressure may need to be adjusted by a service person if HENG blending is stable as received by appliances and equipment to maintain acceptable performance. For some important end-use technologies, adjustment of manifold pressures cannot be performed to respond to these changes.

However, it is important to note that for both the two-stage furnaces and the modulating furnace, only full heating mode (full input) was used for testing so that switching of modes for the two-stage furnace and modulating mode for the modulating furnace were not directly tested or represented in the test results. In the case of the modulating furnace though, the modulating function might be expected to contribute to more precise matching of burner input to fan speed and result in differences in combustion performance. Nevertheless, condensing combustion from differences in combustion product composition might alter flue loss efficiency under the actual operating conditions, which was used as a proxy of rated performance efficiency.

Appliances with adjustments for manifold pressure might be optimized for operation on HENG blends to maintain input and acceptable flame behaviours. However, such adjustments would only be justified if gas supplies to accommodate HENG blends were consistent over time. As a practical matter, adjusting appliance manifold pressures for HENG blends that might revert to more traditional natural gas compositions might result in overfiring and problematic flame behaviours, including overproduction of CO. More modern, non-modulating appliances that do not have adjustable manifold pressures do not raise this concern, but changes in appliance performance from varying gas compositions, such as between HENG blends and traditional natural gases, would need to be anticipated and accounted for in evaluating appliances in the field, such as during combustion efficiency and emissions tests.

It is important to point out that the testing of baseline gas and HENG blends formulated from pure methane provided a measure of consistency across the tests by avoiding the introduction of variability in natural gas compositions that might have influenced results had the baseline gas and HENG blends been formulated from distribution system-supplied natural gas. Additionally, HENG blends used in the testing appear to be within the ranges of applicability of standard natural gas interchangeability criteria such as HHV and Wobbe number limits used in gas supply contracts and tariffs. However, the extension of these criteria to higher percentages of hydrogen may be unjustified, just as extrapolation of these test results to these higher percentages would be unjustified.

Common diluents of natural gas including nitrogen and higher order hydrocarbons such as ethane and propane may have produced different results since these potential natural gas constituents alter gross properties of natural gas such as HHV and Wobbe number. Since HENG might be inconsistently provided to end use appliances due to differences in blending practices and pipeline network delivery, adjustment of appliances to a HENG may not be a practical alternative since the delivered gases (HENG and conventional natural gases) may be highly transient in composition. As a consequence, future testing of even the HENG blend rate of hydrogen (5% and 15%) ought to incorporate more realistic natural gases to determine more representative results.

5 Conclusions

The significance of this study is in addressing the question of whether hydrogen gas blends of up to 15% would affect the operability of space and water-heating appliances in the context of North American standards. Testing demonstrated a consistent decrease in CO_2 emissions and heat outputs. No other obvious trends were noted in regard to other behaviours. The study indicated the need for continued examination of the use of hydrogen with natural gas and possible increased amounts of gas mixtures to achieve the same heat demands. Further validation of the results would require a larger sample size, other types and capacities of appliances, and additional test conditions.

References

[1] U.S. Energy Information Administration, "Residential energy consumption survey," 2015 [Online]. Available: https://www.eia.gov/consumption/residential/

[2] *Biogas – Biogas Production, Conditioning, Upgrading and Utilization – Terms, Definitions and Classification Scheme,* ISO 20675:2019, International Organization for Standardization, Geneva, Switzerland, 2019.

[3] National Grid and Atlantic Hydrogen Inc., "Hydrogen-enriched natural gas: Bridge to an ultra-low carbon world," 2009. [Online]. Available: https://www.osti.gov/etdeweb/servlets/purl/21396875

[4] M.W. Melaina, O. Antonia, and M. Penev, M., *Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues,* National Renewable Energy Laboratory, Mar. 2013. [Online]. Available: https://www.energy.gov/sites/default/files/2014/03/f11/blending_h2_nat_gas_pipeline.pdf

[5] British Gas, "History of British Gas." [Online]. Available: https://www.britishgas.co.uk/business/history (accessed Mar. 22, 2021).

[6] USA Federal Energy Regulatory Commission, "Policy statement on provisions governing natural gas quality and interchangeability in interstate natural gas pipeline company tariff," Jun. 15, 2006. [Online]. Available: https://www.ferc.gov/sites/default/files/2020-04/G-1_29.pdf

[7] TransCanada PipeLines Ltd., "Transportation tariff: General terms and conditions," Feb. 1, 2021. [Online]. Available http://www.tccustomerexpress.com/docs/ml_regulatory_tariff/20%20General%20Terms%20and%20Conditions.pdf

[8] Y. Zhao, V. McDonell, and S. Samuelsen, "Influence of hydrogen addition to pipeline natural gas on the combustion performance of a cooktop burner," *Int. J. Hydrogen Energ.,* vol. 44, no. 23, pp. 12239-12253, May 2019.

[9] NGC+ Interchangeability Work Group, "White paper on natural gas interchangeability and non-combustion end use," Feb. 28, 2005. [Online] Available: https://www.beg.utexas.edu/files/cee/legacy/NGC_Interchangeability_Paper.pdf

[10] *Gas-Fired Central Furnaces,* ANSI Z21.47-2016/CSA 2.3-2016, CSA Group, Toronto, ON, CAN, 2016.

[11] *Gas-Fired Low Pressure Steam and Hot Water Boilers,* ANSI Z21.13-2017/CSA 4.9-2017, CSA Group, Toronto, ON, CAN, 2017.

[12] *Gas Water Heaters, Volume I, Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less,* CSA/ANSI Z21.10.1:19/CSA 4.1:19, CSA Group, Toronto, ON, CAN, 2019.

[13] *Gas-Fired Room Heaters, Volume II, Unvented Room Heaters,* CSA/ANSI Z21.11.2:19, CSA Group, Toronto, ON, CAN, 2019.

[14] H_2 Hydrogen Tools, "Hydrogen compared with other fuels," [Online]. Available: https://h2tools.org/bestpractices/hydrogen-compared-other-fuels (accessed Mar. 22, 2021).

[15] U.S. Environmental Protection Agency, "Natural gas combustion," chapter 1.4, in *Air Emissions Factors and Quantification,* 1998. [Online] Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf

[16] South Coast Air Quality Management District Protocol, "Nitrogen oxides emissions compliance testing for natural gas-fired water heaters and small boilers," Mar. 1995. [Online]. http://www.aqmd.gov/docs/default-source/laboratory-procedures/methods-procedures/r1121_1146-2_prot.pdf

[17] American Gas Association, *AGA gas interchangeability program,* Dec. 12, 2001. [Online]. Available: https://www.techstreet.com/standards/aga-gas-interchangeability-program?product_id=1280332

[18] R.S. Brokaw, "Calculation of flue losses for high efficiency furnaces and appliances," *ASHRAE J.,* vol. 21, pp. 49–51, 1979.

Appendix A: Tested Appliances Specifications

Residential Furnaces

Table A1: Specifications of Tested Residential Furnaces

	FURN1	FURN2	FURN3	FURN4
Combustion control	2-stage	2-stage	2-stage	Modulating
Heat exchanger	Non-condensing	Non-condensing	Condensing	Condensing
Venting type	Induced draft	Induced draft	Induced draft	Forced draft
Ignition type	Electric	Electric	Electric	Electric
Gas manifold pressure (in wc)	3.5	3.5	3.5	3.5
Max input rate (Btu/h)	80,000	80,000	80,000	80,000
Temp rise range (°F)	30–60	30–60	45–75	40–70
Min static pressure	0.15	0.15	0.2	0.2
Max static pressure	0.5	0.5	0.5	0.5
Min input rate (Btu/h)	52,000	52,000	56,000	28,000
Temp rise range (°F)	20-50	20-50	20-50	20-50
Annual Fuel Utilization Efficiency (AFUE)	80%	80%	96%	97.5%

Residential Boilers

Table A2: Specifications of Tested Residential Boilers

	BLR1	BLR2	BLR3	BLR4
Combustion control	1-stage	1-stage	Modulating	Modulating
Heat exchanger	Non-condensing	Non-condensing	Condensing	Condensing
Venting type	Draft hood	Vent damper	Direct vent	Direct vent
Ignition type	Electric spark to pilot	Electric	Electric	Electric
Gas manifold pressure (in wc)	3.5	4	Not applicable	Not applicable
Max input rate (Btu/h)	96,000	100,000	100,000	120,000
Min input rate (Btu/h)	Not applicable	Not applicable	10,000	13,200
Annual Fuel Utilization Efficiency (AFUE)	82%	85%	95%	95%

Residential Water Heaters

Table A3: Specifications of Tested Residential Water Heaters

	WH1	WH2
Combustion control	1-stage	1-stage
Heat exchanger	Non-condensing	Non-condensing
Venting type	Power	Draft hood
Ignition type	Electric	Electric
Gas manifold pressure (in wc)	4	5
Max input rate (Btu/h)	40,000	40,000
Min input rate (Btu/h)	Not applicable	Not applicable
Tank capacity	50 gallon	40 gallon
Amount of heated water produced per hour (Recovery)	37.8 gallon	43.1 gallon
Other description	Energy star	Ultra-low NOx

Residential Unvented Space Heaters

Table A4: Specifications of Tested Unvented Space Heaters

	SP1	SP2
Combustion control	Manual gas valve	Manual gas valve
Heat exchanger	Not applicable	Not applicable
Burner type	Blue Flame – no electric	Infrared – no electric
Venting type	Unvented	Unvented
Ignition type	Pilot ignition	Pilot ignition
Gas manifold pressure (in wc)	3.5	6.0
Max input rate (Btu/h)	30,000	30,000
Min input rate (Btu/h)	8,500	8,000

Appendix B: Detailed Results

Residential Furnaces

Table B1: Input Rate of Residential Furnaces Measured at Normal and 87% of Minimum Input Rate Under Normal External Static Pressure

		Normal Input Rate			87% of Minimum Input Rate		
	Test Gas	Manifold Pressure (in wc)	15-min Input Rate (Btu/h)	Temp Rise (°F)	Manifold Pressure (in wc)	15-min Input Rate (Btu/h)	Temp Rise (°F)
FURN1	CH_4	3.8	79,050	42.0	1.3	44,920	28.1
	5% H_2	3.8	76,670	39.6	1.3	44,580	27.6
	15% H_2	3.8	75,730	39.2	1.3	43,360	25.3
FURN2	CH_4	3.9	79,420	42.7	1.4	46,450	34.4
	5% H_2	3.9	77,760	42.7	1.4	44,890	32.8
	15% H_2	3.9	75,710	43.6	1.4	43,470	32.2
FURN3	CH_4	3.7	80,290	59.9	1.4	48,010	47.2
	5% H_2	3.7	79,030	58.8	1.4	47,510	46.5
	15% H_2	3.7	75,920	56.7	1.4	45,600	45.0
FURN4*	CH_4	3.9	79,220	58.1	0.65	30,920	44.7
	5% H_2	3.9	78,210	59.2	0.65	30,920	45.0
	15% H_2	3.9	76,880	59.2	0.65	31,050	44.6

***FURN4 is a modulating furnace. Internal control function maintains temperature rise with changes in input rate.**

Table B2: Combustion Gas Properties of Residential Furnaces Under High Input Rate

Furnace	Test Gas	CO_2%	CO AF (ppm)	Flue Temp (°F)	Flue Loss (%)	Dew Point (°F)	Condensate pH	NO_x AF at Steady-state (ppm)
FURN1	CH_4	4.55	24	336.8	21.9	110.4	NA	79.1
	5% H_2	4.43	23	331.0	21.9	110.3	NA	77.8
	15% H_2	4.10	25	328.1	22.4	109.4	NA	80.6
FURN2	CH_4	7.48	28	400.2	19.6	125.1	NA	80.5
	5% H_2	7.26	24	394.7	19.6	124.8	NA	80.4
	15% H_2	6.76	20	385.4	19.9	124.2	NA	78.9
FURN3	CH_4	8.47	18	104.6	4.2	128.5	3.83	84.8
	5% H_2	8.16	17	104.4	4.2	128.1	3.67	86.0
	15% H_2	7.64	10	103.2	4.0	127.9	3.63	80.9
FURN4	CH_4	8.12	25	104.9	4.8	126.4	3.73	77.3
	5% H_2	7.77	29	104.3	4.6	126.6	3.73	87.4
	15% H_2	7.32	20	104.3	4.8	126.4	3.73	84.5

NA – not applicable.

Residential Boilers

Table B3: Input Rates of Residential Boilers Measured at High Manifold Pressures

	Test Gas	Manifold Pressure (in wc)	15-min Input Rate (Btu/h)	Steady-state Input Rate (Btu/h)
BLR1	CH_4	3.7	95,100	95,200
	5% H_2	3.7	92,920	92,950
	15% H_2	3.7	90,490	90,200
BLR2	CH_4	4.5	99,560	99,890
	5% H_2	4.5	98,150	98,080
	15% H_2	4.5	96,630	96,267
BLR3	CH_4	NA	96,010	93,720
	5% H_2	NA	95,710	94,160
	15% H_2	NA	92,020	91,000
BLR4	CH_4	NA	116,100	117,300
	5% H_2	NA	114,700	116,500
	15% H_2	NA	112,600	113,200

NA – not applicable.

Table B4: Combustion Gas Properties of Tested Residential Boilers at High Input Rate

Boiler	Test Gas	CO_2%	CO AF (ppm)	Flue Temp (°F)	Flue Loss (%)	Dew Point (°F)	Condensate pH	NO_x AF at Steady-state (ppm)
BLR1	CH_4	4.20	17	269	19.6	107.9	NA	137.3
	5% H_2	3.74	9	269	20.6	105.3	NA	130.9
	15% H_2	3.45	10	266	21.1	104.6	NA	132.0
BLR2	CH_4	5.33	70	243	16.8	115.0	NA	115.5
	5% H_2	5.15	79	236.5	16.7	114.7	NA	117.0
	15% H_2	4.79	35	237.7	17.1	114.6	NA	108.3
BLR3	CH_4	9.00	150	126.7	8.1	130.6	2.56	32.1
	5% H_2	8.76	122	126.9	8.4	130.6	2.53	26.9
	15% H_2	8.26	88	128	9.2	130.6	2.40	21.5
BLR4	CH_4	9.15	124	122.3	5.9	131.0	2.73	31.5
	5% H_2	8.89	103	121.6	5.9	130.9	2.93	26.9
	15% H_2	8.58	74	122.8	6.4	132.0	3.00	23.0

NA – not applicable.

Residential Water Heaters

Table B5: Input Rates of Residential Water Heaters at High Manifold Pressures

	Test Gas	Manifold Pressure (in wc)	15-min Input Rate (Btu/h)	Steady-state Input Rate (Btu/h)
WH1	CH_4	4.5	39,900	39,600
	5% H_2	4.5	39,500	39,200
	15% H_2	4.5	38,100	37,800
WH2	CH_4	4.5	39,600	39,700
	5% H_2	4.5	38,900	39,000
	15% H_2	4.5	38,200	38,100

Table B6: Combustion Gas Properties of Tested Residential Water Heaters Under High Input Rate

	Test Gas	CO_2%	CO AF (ppm)	Flue Temp (°F)	Flue Loss (%)	Dew Point (°F)	Condensate pH	NOx AF at Steady-state (ppm)
WH1	CH_4	1.91	8	161.2	19.3	85.6	NA	107.3
	5% H_2	1.82	2	160.0	19.6	84.3	NA	108.2
	15% H_2	1.80	8	160.3	19.6	86.3	NA	103.8
WH2	CH_4	5.77	12	314.0	18.9	117.3	NA	16.45
	5% H_2	5.44	21	315.5	19.4	115.9	NA	14.8
	15% H_2	5.00	16	311.0	19.8	114.7	NA	11.05

NA – not applicable.
Note: CO_2 levels of WH1 measured in the combustion gas were mixed with dilution air drawn into the vent from outside the water heater.

Residential Unvented Space Heaters

Table B7: Input Rates of Residential Unvented Space Heaters Measured at High Input rates

	Test Gas	Manifold Pressure (in wc)	15-min Input Rate (Btu/h)
SP1	CH_4	3.5	29,930
	5% H_2	3.5	29,490
	15% H_2	3.8	29,800
SP2	CH_4	6.2	29,400
	5% H_2	6.2	29,260
	15% H_2	6.2	27,890

Table B8: Combustion Gas Properties of Tested Residential Unvented Space Heaters

	Test Gas	CO_2%	CO AF (ppm)	NO_2 AF (ppm)
SP1	CH_4	0.94	12	10.3
	5% H_2	1.04	56	11.4
	15% H_2	1.02	33	8.8
SP2	CH_4	1.08	65	10.2
	5% H_2	0.88	66	10.6
	15% H_2	0.83	68	12.5

Table B9: Metal Guard High Temperature (°F) of Tested Blue Flame Residential Unvented Space Heaters at Various Positions

Test Gas	Position	Left	Middle	Right
CH_4	Top	187	265	175
	Bottom	112	181	116
5% H_2	Top	206	380	184
	Bottom	126	149	136
15% H_2*		-	-	-

***Main and pilot flame extinguished after 30 minutes; therefore, test not completed.**

Table B10: Metal Guard High Temperature (°F) of Tested Infrared Residential Unvented Space Heaters at Various Positions

Test Gas	Position	Left	Middle	Right
CH_4	Top	180	340	187
	Middle	191	306	182
	Low	195	320	187
5% H_2	Top	200	319	190
	Middle	188	316	201
	Low	176	357	185
15% H_2	Top	199	371	195
	Middle	201	327	193
	Low	194	312	192

Table B11: Infrared Burner Surface High Temperature (°F) of Tested Infrared Residential Unvented Space Heaters at Various Positions

Test Gas	Positions Along the Width of the Space Heaters at Equal Distances from Left to Right				
CH_4	1120	1180	1195	1165	1120
5% H_2	1100	1121	1131	1114	1047
15% H_2	1023	1110	1200	1130	1060

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

Scott Stauffer

From: Eric Corey Freed <eric@organicarchitect.com>
Sent: Wednesday, November 2, 2022 10:24 AM
To: OCR
Subject: Electrification Support

This Message originated outside your organization.

Dear Councilmembers:

My name is Eric Corey Freed. I contributed to the City of Milwaukie Climate Action Plan and am a nationally known green architect and expert in decarbonizing buildings.

I am writing to express my support for the three resolutions before Council committing to transition homes and buildings off of polluting fossil fuels and to clean renewable electricity.

The climate crisis cannot wait. Milwaukie has been a climate leader in Oregon, and we should continue to lead the way in this important time for climate action. Burning gas in buildings is harmful to public health and the buildings sector is the second highest source of greenhouse gas emissions in the state.

To tackle the climate crisis and ensure healthy and affordable communities, we must build without gas, retrofit our aging existing homes, and lead by example so that other Oregon communities follow. I urge you to support these three commonsense yet critical policies that will make Milwaukie a cleaner, safer, and more affordable place to live.

Sincerely,

-eric

Eric Corey Freed, RA, LEED Fellow, EcoDistricts AP, LFA, ActiveScore AP
–
Principal, Director of Sustainability

CannonDesign

T 415.474.7777
cannondesign.com

Scott Stauffer

From: Lisa Batey
Sent: Wednesday, November 2, 2022 3:16 PM
To: OCR
Subject: Fwd: natural gas in Milwaukie-last night's meeting

Scott, another for the record…

Sent from my iPhone

Begin forwarded message:

> **From:** Barbara EPIDENDIO <bepidendio@msn.com>
> **Date:** November 2, 2022 at 2:48:59 PM PDT
> **To:** Adam Khosroabadi <KhosroabadiA@milwaukieoregon.gov>, Lisa Batey <BateyL@milwaukieoregon.gov>, Desi Nicodemus <NicodemusD@milwaukieoregon.gov>, Kathy Hyzy <HyzyK@milwaukieoregon.gov>
> **Subject: natural gas in Milwaukie-last night's meeting**
>
> Hello Councilors,
>
> Thank you for your desire to investigate more deeply what banning natural gas to people like me, that is, a Milwaukie resident, would do.
>
> I heat my home, my water, dry my clothes,cook with nat gas. And even with all that service and comfort, gas is my lowest utility bill and no matter the weather, snow, ice, wind, that utility is reliable.
>
> Listening to Mayor Gamba and Natalie last night, I didn't hear anyone address the costs, not just to implement the resolutions, but the ongoing increased costs to heat those city buildings. Once again, the residents of Milwaukie will have a hidden tax imposed on them because we're the people who pay for all city operations.
>
> The tenants, owners in the new construction to Milwaukie will also bear higher than necessary costs with no choices in energy sources. Affordable housing is more than the initial costs to buy, rent housing.
>
> If I were a business that needed reasonably-priced-energy to make my products the energy types available would be top of my list before I bought, leased, started a business. We'll never know how many companies passed Milwaukie by when they saw they had only one energy source.
>
> There may well be funds "out there" to make these aspirations become reality, but right now, they are vaporous, will take years to be certain of.

As for the Climate Fund, it seems cavalier for the council to just try to slip another "levy", "fee", "tax", just like the SAFE fee on us.

It was interesting to me to hear Mayor Gamba trash NWN, contractors, as he promotes taking a utility away from the citizens.

No, I don't work for NWN, nor have any family members, friends that do, nor do I own any NWN stock.

I'm appreciative of you wanting to be very sure of what's being contemplated in considering the banning of nat. gas. 2035 is a nice goal, but it's not written in stone, and hasty decisions shouldn't be made because of it

Sincerely,

Barbara Epidendio
11520 SE Stanley Ave.
Milwaukie