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How about the consequences for the end-user?
-
Performance of *Existing* Natural Gas Appliances

Dr. Harmen de Vries,
assistance from Prof.Dr. Howard B. Levinsky
N.V. Nederlandse Gasunie

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Safe gas application: $[H_2]_{max}$?

- The maximum allowable hydrogen concentration $[H_2]_{max}$ in the mixture with NG in the current situation ?
  (no appliance re-adjustment, just add the H_2)
- Intrinsic connection with natural gas distribution conditions
- Combustion safety aspects
- Focus on domestic appliances

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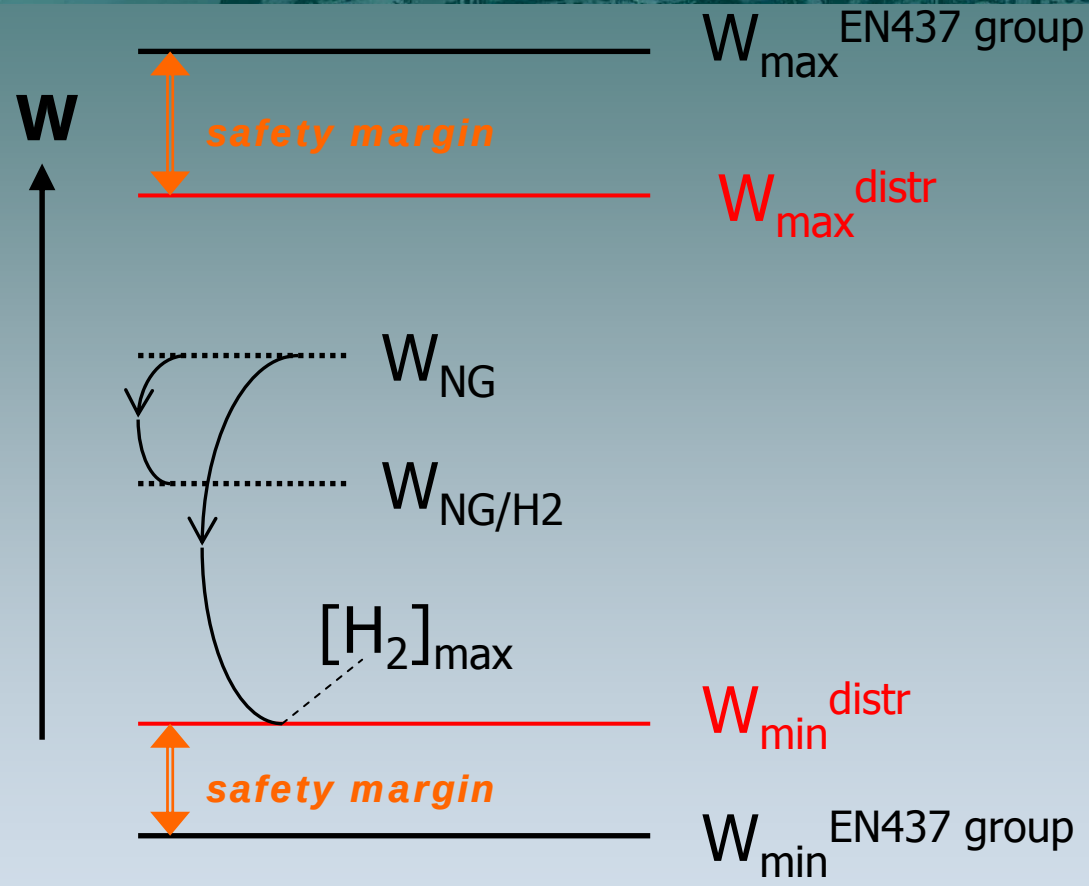
$[H_2]_{max}$ limit by distribution condition



Distribution condition: $W_{NG/H2} \geq W_{min}^{distr} > W_{min}^{EN437\ group}$

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Gas interchangeability and appliances

- Add H_2: *new* gas → interchangeability issue (familiar)
- Test large numbers of (or all ?) appliances ?
- Fundamental approach / assessment method
  - Current knowledge of combustion (H_2 !)
  - General operating principle of domestic appliances
  - **For any national / local situation**
  - **Justified output statements without large scale testing**

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Premixed appliance operation

- *Constant fuel gas pressure, constant air flow rate*
- $\Phi_{prim} = (F/A) / (F/A)_{stoich}$
- Appliance operational Φ_{prim} changes upon changing fuel gas composition: **Φ - shift**
- *Stable* flame front: prerequisite for appliance safety ($S_L = v_u$)
- Well-known: **S_L (H_2) > S_L (hydrocarbons)**
- Flame front stability endangered by **Risk of Light-back ($S_L > v_u$)** upon H_2 addition

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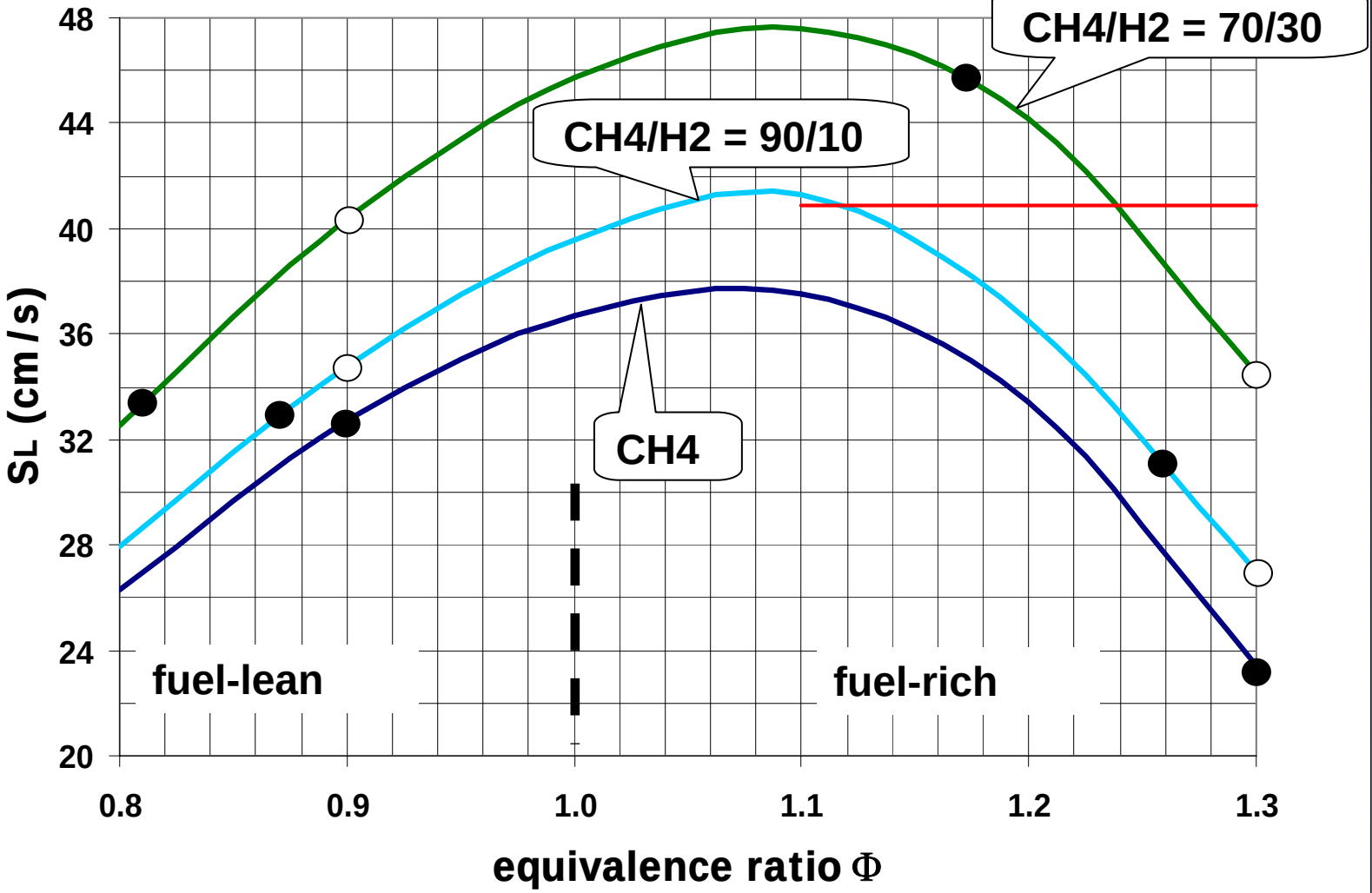
ΔS_L , $\Delta\Phi$: light-back propensity , $[H_2]_{max}$



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Viewpoint: W-band

- EN437 testgas Wobbe bands and Wobbe distribution bands apply on a national or regional scale
- The appliances of different type all are connected to one and the same national or regional NG distribution grid
- It is practical to consider *detailed results from the viewpoint of a W-band*

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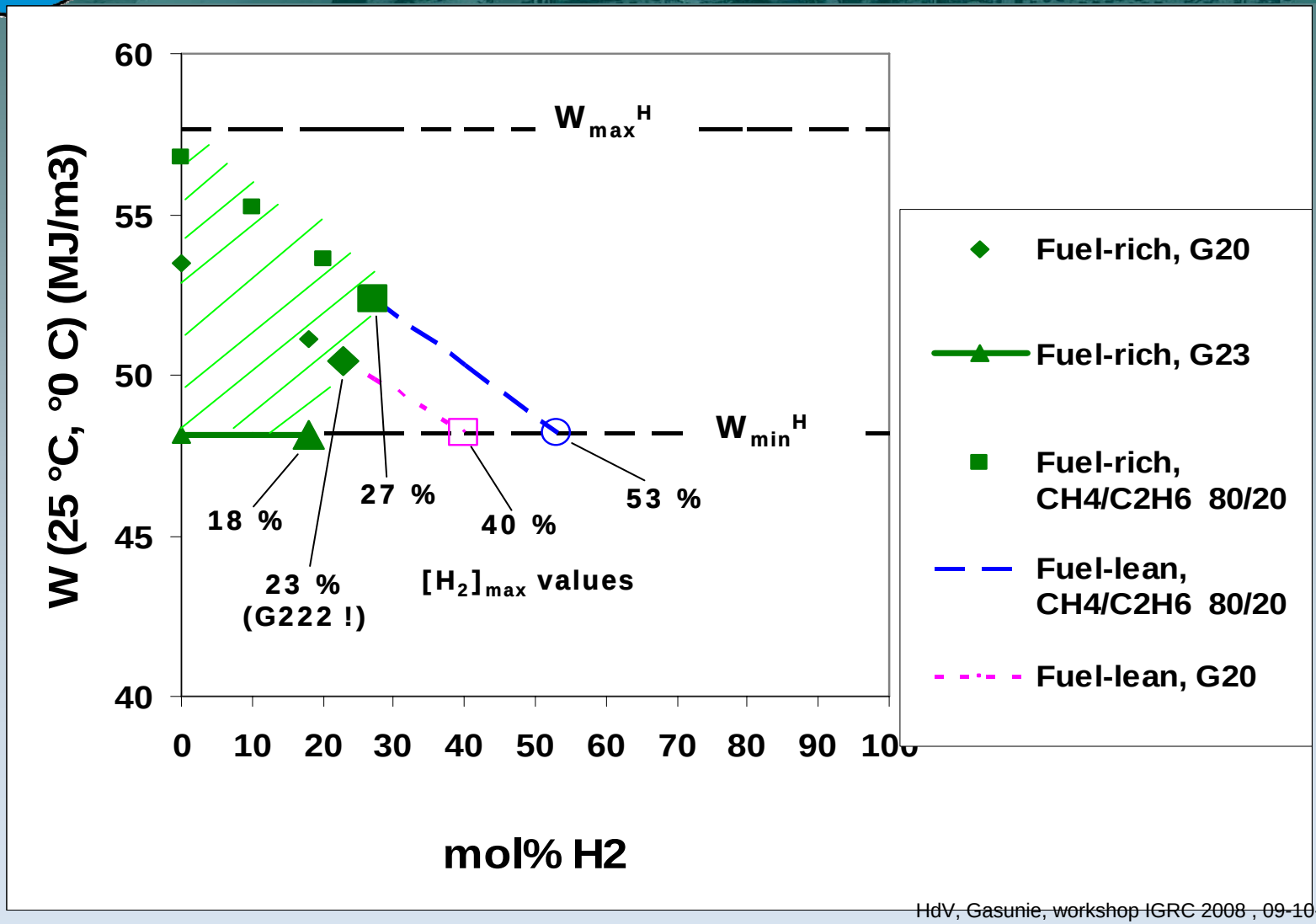
Domestic appliances: H-band-like distribution -- working area



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H-band-like distribution working area

- New/properly-serviced domestic appliances
- "constant fuel gas pressure, constant air flow rate"
- Light-back reference: G222 light-back limit gas
- Appliance adjustment: Φ = 1.3 with G20
- $[H_2]_{max}$ values in the range from 0% up to ~ 28% may apply, dependent on initial natural gas
- Additional work needed

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Conclusions: domestic appliances (1)

- **Method** illustrated is **applicable to any local situation** without large-scale appliance testing
- **Large differences from country to country**: NG Wobbe values & distribution bandwidths , appliance adjustment practices
- Up to ~90% H_2 , **thermal input will decrease** to all combustion equipment, except those having power controls (decreasing user-comfort)
- **Fuel-rich appliances**:
  - **light-back** possible at low levels of H_2

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Conclusions: domestic appliances (2)

- **Fuel-lean appliances**:
  - **no light-back** problems **expected** up to >~ 50% H_2
  - **NO_x emissions** expected to **decrease**
  - **efficiency will decrease slightly** (or at best remain constant)
  - **Inferior calorific value based efficiency**
    → **misinterpretation** of the actual effect of H_2 addition

- **Long-term (~ 15 years) material compatibility** of appliances **with H_2 still uncertain**

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Large scale gas utilization: no general analysis from fundamentals

- **Stationary NG engines** perform close to knock-limit:
  - Readjustment and/or modification of control system necessary
  - Don't like H_2 concentration variations
- **Modern gas turbines** have tight fuel specs
  - Outside these specs readjustment and/or costly modification of control system necessary
  - Manufacturers' permission needed
  - Unannounced H_2 concentration variations unacceptable
- Natural **gas as a chemical feedstock**: H_2 admixture possibly very undesirable
- Consequences for all the different **industrial combustion applications** have to be considered from case to case

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